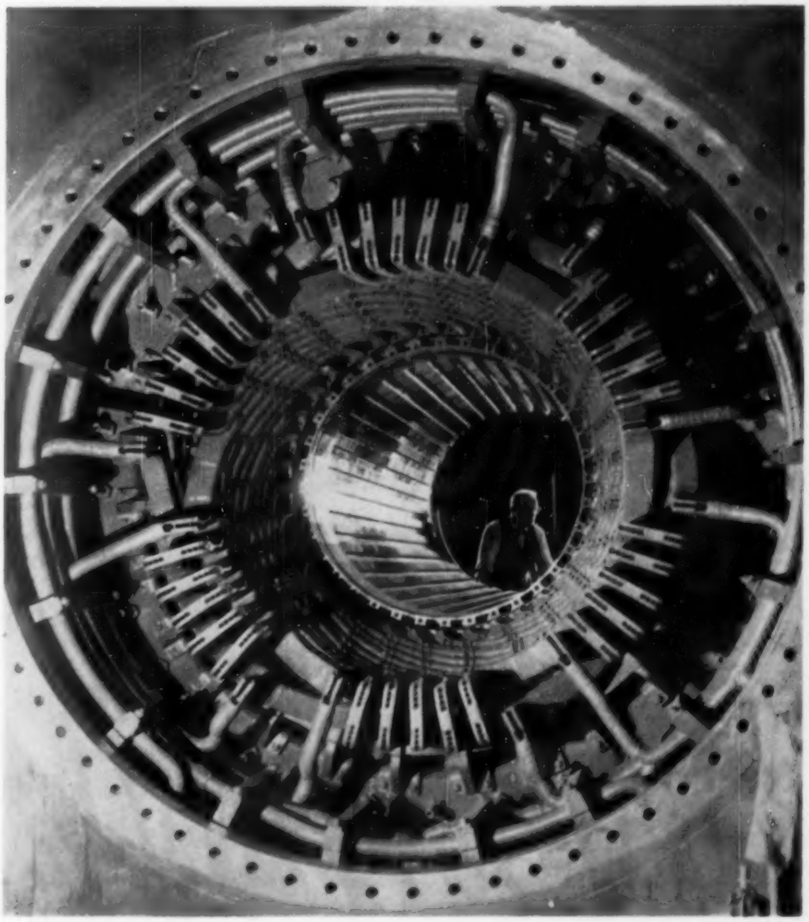
Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



February 1961

Furnace Safeguards Panel

Optimizing Regenerative Steam Cycles

Hiring Engineering Graduates

Power Plant Clinic

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

volume 32 number 8 **February 1961**

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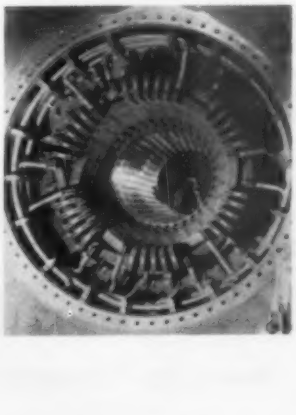
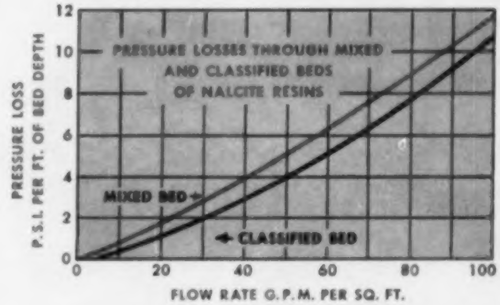
COVER PHOTO

Copper coil strands are transposed around stainless steel tubing. Hydrogen gas passes through the coils. (Courtesy Allis-Chalmers Mfg. Co.)



How to Make Your Demineralizers GROW: Replace Worn-out Resins with New Nalcite® Ion Exchangers

Added Capacity Teams With Higher Flow Rates, Less Pressure Drop, To Increase Demineralized Water Output at Low Cost



Demineralizers are like storage space—you can always use more capacity . . . And new Nalcite resins can help you get that added capacity from your present demineralizer installation.

"Better than new" is a practical prospect with Nalcite resins. They not only outperform older Nalcite ion exchange materials (which were as good as could be made at the time), but they also have longer useful life.

New Nalcite Resins Stay New

Nalcite HCR-W* cation and Nalcite SBR-P* anion exchangers were designed to eliminate the enemies of ion exchanger performance: strong resistance to bead breakage and loss, and organic fouling, keeps capacities up, resin addition down.

Nalcite SBR-P Anion Exchange resin has taken a leading place in the water demineralization field since its introduction in 1957. It is a strongly-basic anion exchanger with both high porosity and high capacity. While it is especially suited for waters containing organic matter and color, its high capacity and efficiency are good reasons to consider it as replacement for worn out type 2 as well as type 1 resins. It can be used effectively on all types of water supplies. Brine washing to remove organic matter and color has been eliminated in several demineralizers now using Nalcite SBR-P in place of older type resins. Excellent particle size characteristics add to the efficiency of Nalcite SBR-P. Optimum bead size facilitates foreign matter removal, minimizes expansion during backwash, and permits use of less freeboard in many installations. High flow rate mixed bed demineralization and applications which subject resin to considerable physical handling are other areas where Nalcite SBR-P has proved an outstanding performer.

Nalcite HCR-W* Cation Exchange resin has the high degree of sphericity and very narrow range of particle size distribution that assure low operating pressure losses in both mixed and classified bed demineralizers. Virtually stress-free HCR-W spheres reduce breakage due to regeneration, high flow rates or other causes—including drying. Nalcite HCR-W beads also resist channeling and packing. Nalcite HCR-W has excellent physical and chemical stability under most severe demineralizer operating conditions, plus high exchange capacity to make your demineralizers grow in efficiency for you.

Replace All or Part of Resin?

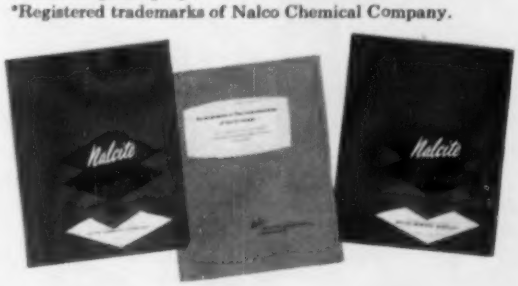
Replacement of entire beds with Nalcite SBR-P and HCR-W is the way to boost demineralizer performance and capacities to top efficiency. Partial bed replacement may be made with Nalcite HCR-W, regardless of the type of cation resin used, but due to possible density differences which may adversely affect anion exchanger performance, addition of SBR-P to other anion exchangers, exception in mixed beds, should be made only after study. To be sure of your replacement resin benefits, consult your demineralizer equipment manufacturer, who can engineer these new improved ion exchangers into your demineralizer. Write us if you have any questions.

Data on Ion Exchangers

Progress in the practical science of using ion exchangers efficiently is discussed in Nalco Reprint 84: "Developments in the Understanding of Ion Exchange." Practical ion exchanger applications, improved laboratory methods, new ion exchange materials, and more efficient operating technique are discussed.

New Nalco Bulletins: (HCR-W) Z12 and (SBR-P) Z13 provide extensive technical information on these efficient Nalcite Ion Exchangers. Your request for any or all bulletins will be honored promptly.

*Registered trademarks of Nalco Chemical Company.



NALCO CHEMICAL COMPANY
Ion Exchange Division
6234 West 66th Place • Chicago 38, Illinois
Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany
In Canada: Alchem Limited, Burlington, Ontario

Nalco®... *Serving Industry through Practical Applied Science*

Unlike conventional electrical or pneumatic valves, new electro-hydraulically operated Hydramotors remain in last position when power is removed – until energized to trip. Designed by General Controls for use on the main gas and oil fuel lines of power plants, these Hydramotors are especially built and internally wired to close tightly in just one second – *but only on operator command.*

This eliminates the possibility of shutdown in case of power source failure...keeps flow to boilers constant at all times because these valves are electrically operated. No air pressure or pneumatic piping is required.

BE QUALITY SURE...ALWAYS SPECIFY GENERAL CONTROLS

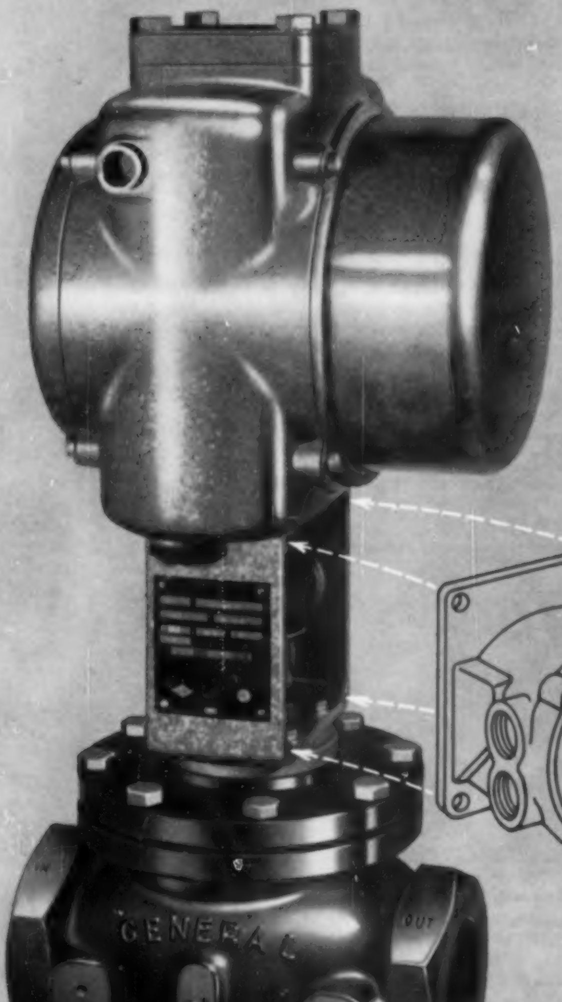
GENERAL CONTROLS

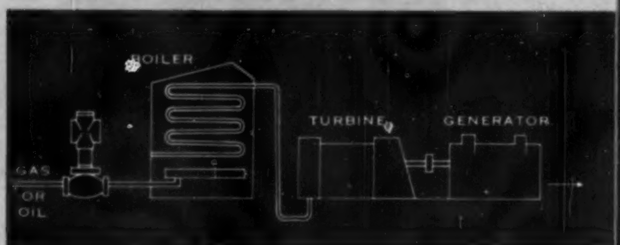
Automatic Controls for Product or Process

Glendale, Calif. • Skokie, Ill. • Guelph, Ontario, Canada

Nine Plants — 44 Factory Branch Offices Serving The United States, Canada and Western Europe

For continuous fuel flow and instant shutoff –just say "when" to these new HYDRAMOTOR® VALVES FOR POWER PLANTS



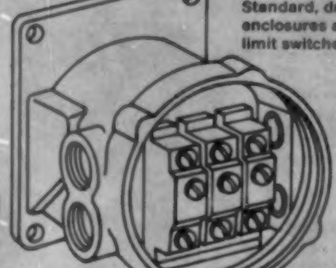


Hydramotor fuel shutoff valves are designed for pipe sizes from ⅜" through 12" and are available with hermetically sealed power units in a choice of two types of actuators.

"KC" type, with simple 3-wire circuitry, uses AC power to open and close the valve. "KA" type, with 4-wire circuitry, meets the requirement of standby power by using AC power to open the valve and DC voltage to close it in case of emergency.

If your requirements are for standard Hydramotors which de-energize to trip either full closed or full open on interruption of power, these are also available.

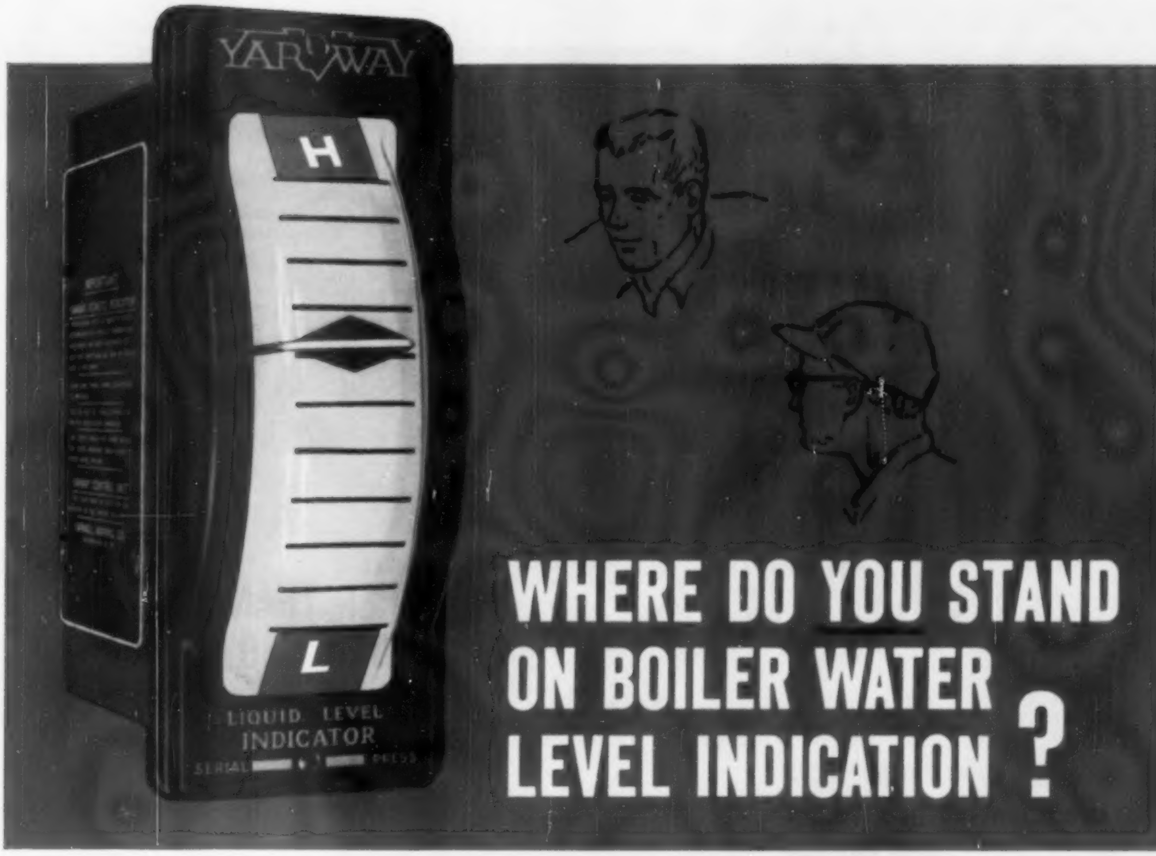
Standard, drip proof, explosion proof and weather proof enclosures are available. Accessories include dust shields, limit switches, potentiometers and manual opening device.



SPECIAL SWITCH UNIT AVAILABLE

An auxiliary switch unit, with three switches that are independent of Hydramotor controls, is available to interlock the shutoff valve with other power plant systems. Each switch is adjustable to trip at any position of valve stroke. This explosion proof, weather proof unit can be mounted in the field. Six SPDT switches may be obtained by using two of the units with a Hydramotor.

Write today for specifications and complete information. Ask for Bulletin SD1-H2, 3KA, C-1 (Hydramotor Shutoff Valves) and Bulletin 608.287 (Auxiliary Switch Unit).



Yarway Remote Indicators have "wide angle" visibility from multiple vantage points

Yarway Remote Liquid Level Indicators bring distant, often hard-to-see boiler level readings right down to eye level on the panel board or other convenient location.

No matter where you stand—at any point in a 180° arc, and from a considerable distance—the brilliant new wide vision dial makes viewing and reading easy.

Accurate readings because Indicator is operated by boiler water itself

Remote readings of levels in boilers (also feed water heaters and other heat exchangers) are instant and accurate because indicator *operating mechanism* is actuated by the varying head of the liquid itself, yet the *pointer mechanism* is never under pressure.

Fully approved under Boiler Code Case #1155

Under A.S.M.E. Boiler Code Committee ruling in Case #1155, two independent remote level indicators of compensated manometric type may be used as primary indicating elements instead of one of the two gage glasses required for boiler pressures 900 psi and above. When both indicators are in operation, one gage glass may be shut off but shall be maintained in serviceable condition.

Yarway Remote Liquid Level Indicators conform to this ruling and are used widely for primary boiler water level indication in plants operating at 900 psi and above.

All Yarway Indicators for service over 700 psi are temperature-compensated; pressure compensation available when desired. Use of controlled-temperature column on constant head chamber fully protects against system upsets.

If you would like a reprint of this Boiler Code ruling, just ask for Case #1155 reprint.

Get the full story on Yarway Liquid Level Indication for your plant. Write for new 24-page Bulletin WG-1825.

YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

YARWAY
A MARK OF QUALITY IN STEAM ENGINEERING

TYPICAL USERS OF YARWAY INDICATORS FROM OVER 15,000 INSTALLATIONS	INDUSTRIAL PLANTS	UTILITIES (Code Case #1155 Installations)	
	WEYERHAEUSER COMPANY		NEBRASKA POWER
	GENERAL ELECTRIC COMPANY	COMMONWEALTH EDISON	NEW ENGLAND POWER
	STAUFFER CHEMICAL COMPANY	ILLINOIS POWER CO.	ROCHESTER GAS & ELECTRIC CO
	U. S. STEEL COMPANY	WISCONSIN POWER & LIGHT	PENNSYLVANIA ELECTRIC CO. (ERIE, PA)
	GENERAL MOTORS	PUBLIC SERVICE OF INDIANA	LOUISIANA POWER & LIGHT
	MOBIL OIL COMPANY	IOWA ELECTRIC LIGHT & POWER	POTOMAC ELECTRIC POWER CO.

WHERE "BUFFALO" TYPE "CR" FANS MEAN

MAJOR DRAFT SAVINGS

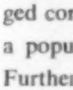
RIGHT FROM THE START

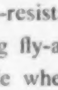
*
The "Q" Factor—the built-in Quality which provides trouble-free satisfaction and long life.

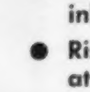
Utilizing a superior radial-tip blade wheel in the same stream-lined housing as the high-efficiency Buffalo Airfoil series, the Type "CR" Fan provides highly satisfactory performance in many punishing applications . . . at lower first cost. For example, its rugged construction and abrasion-resistant qualities make it a popular choice for handling fly-ash in power plants. Further, Buffalo Radial Blade wheels are available in varying widths and depths to meet most pressure-volume requirements efficiently. Write for Bulletin FD 205 and check the "Q" Factor* Features that make Buffalo Mechanical Draft Fans the best buy for your service.

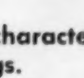
- **Stable performance with or without fixed inlet vanes.**
- **Rising horsepower characteristic for efficiency at dampered ratings.**
- **Excellent for I. D. on stoker-fired or pulverized coal boilers.**
- **Use of smaller fan size possible on many direct-connected installations.**

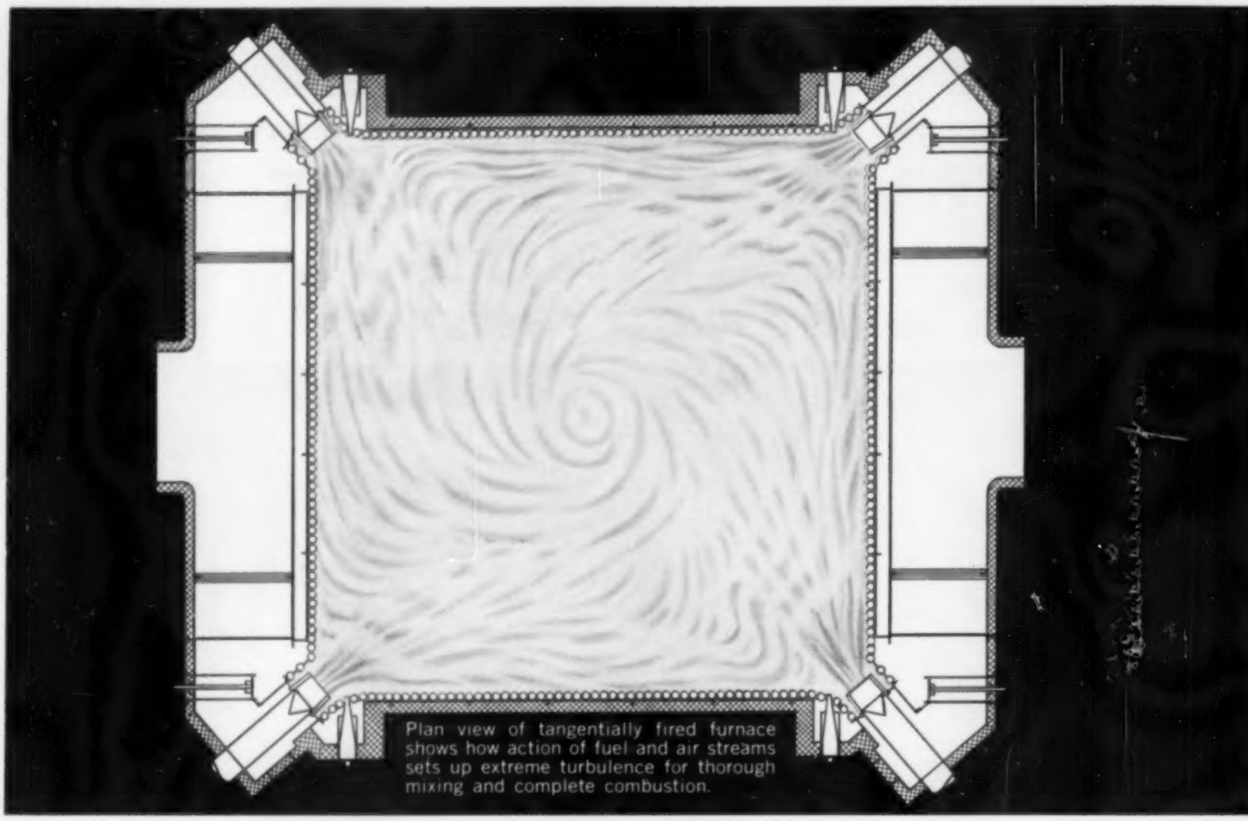
BUFFALO FORGE COMPANY
Buffalo, New York
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.


'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.


'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.

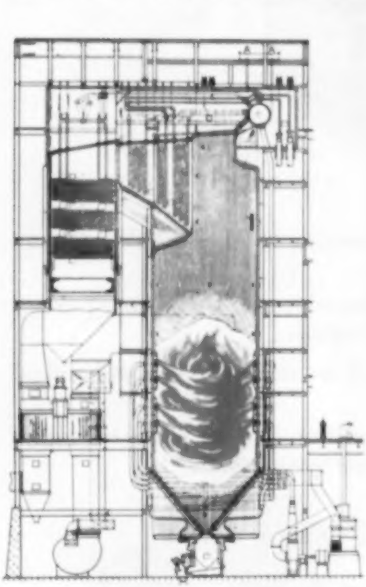

'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.

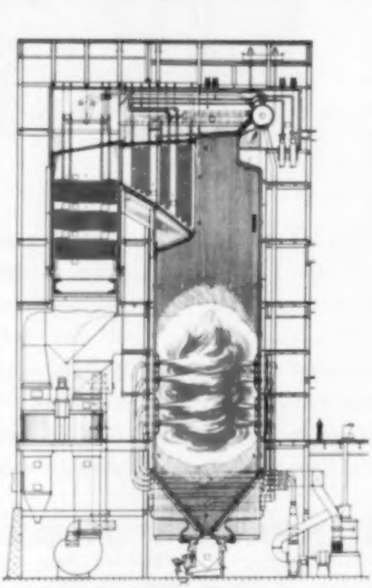

Squier Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.

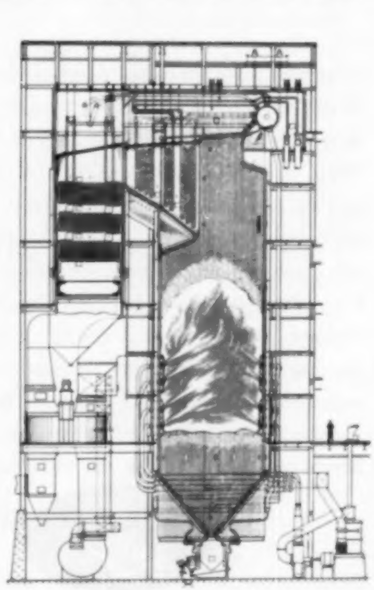


Plan view of tangentially fired furnace shows how action of fuel and air streams sets up extreme turbulence for thorough mixing and complete combustion.

C-E TANGENTIALLY FIRED BOILERS

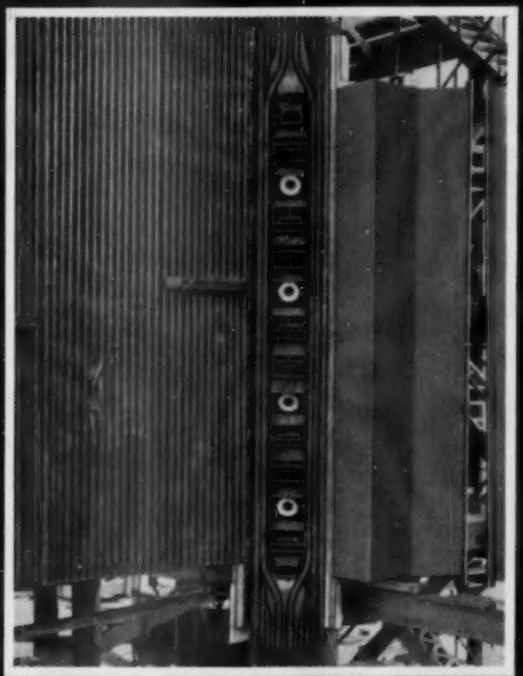






HOW C-E TILTING TANGENTIAL BURNERS CONTROL SUPERHEAT.

First diagram shows burners tilted downward to reduce furnace outlet temperature. Middle diagram shows normal operating position. Third diagram shows upward tilt to send higher temperature gases to superheater.



Erection view showing shop assembled burner panel being placed in position for welding to wall panels. All four corners of the furnace are similarly equipped.

give more complete combustion... most sensitive steam temperature control

Tangential firing—pioneered by Combustion in 1927—is today the most widely accepted method of firing pulverized coal, gas or oil, separately or together, in large utility boilers. Air and fuel are fed to the furnace in a number of relatively small streams which are directed from each of the four corners of the furnace.

This assures intimate mixing and sets up a strong turbulent motion within the furnace . . . to produce the most complete combustion with minimum carbon loss. The combustion gases fill the furnace for more rapid heat transfer to the waterwalls.

The tilting nozzles of C-E Tangential Burners automatically tilt up or down as steam temperature varies. If steam temperature goes too high, the nozzles tilt downward . . . more furnace wall surface becomes effective . . . gas temperature to superheat surface is lowered . . . steam temperature goes down. Or, if steam temperature drops, the nozzles tilt upward . . . hotter gases go to the superheater . . . steam temperature goes up.

Catalog PC-8 gives full information on tangentially fired C-E boilers, including units with capacities as low as 70,000 lb of steam per hour. Write for your copy today.

COMBUSTION ENGINEERING

General Offices: Windsor, Conn. • New York Offices: 200 Madison Avenue, New York 16

C-304

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

We have news for you, if you are concerned with critical piping. It's the information about our shop and field facilities given in an illustrated "Brochure" which we'd like to send to you for your file. Write us now, and on your next high-temperature, high-pressure job . . . ask us in.

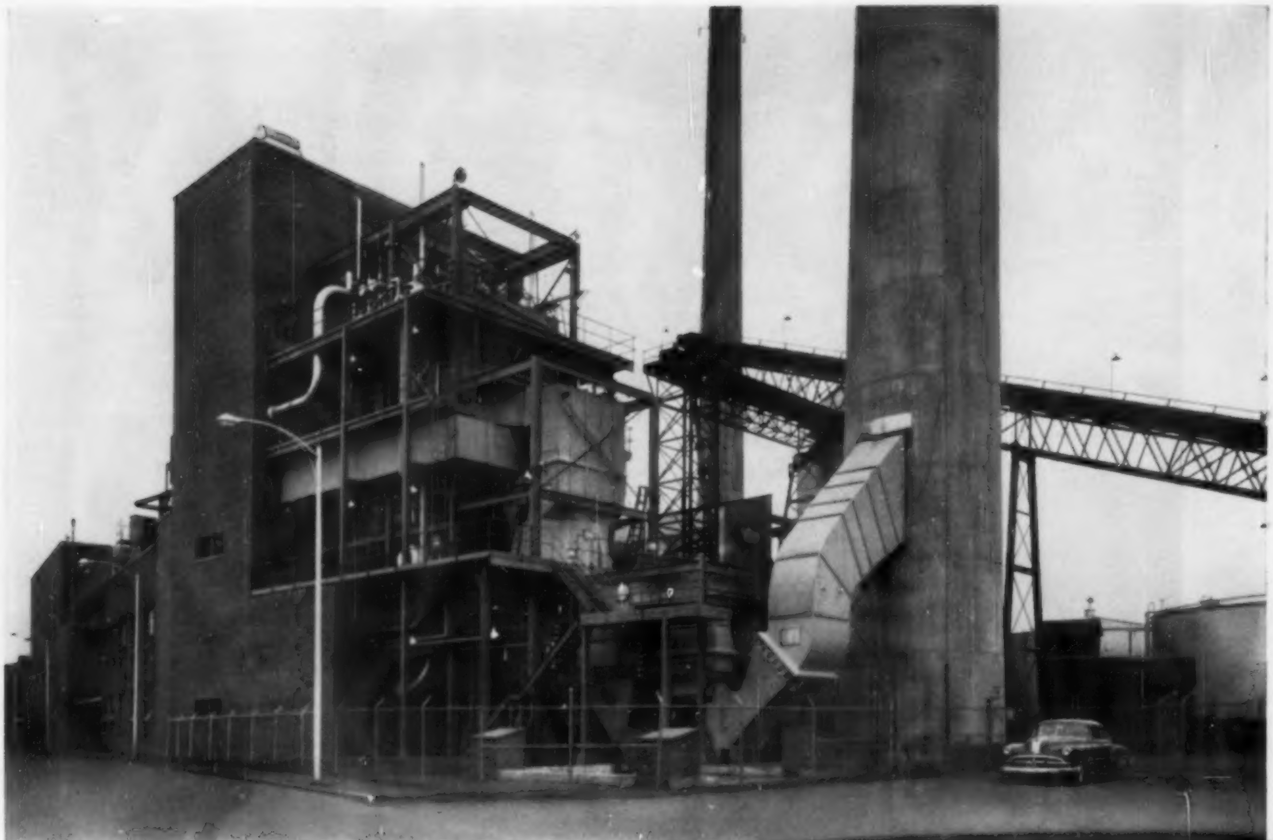
W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

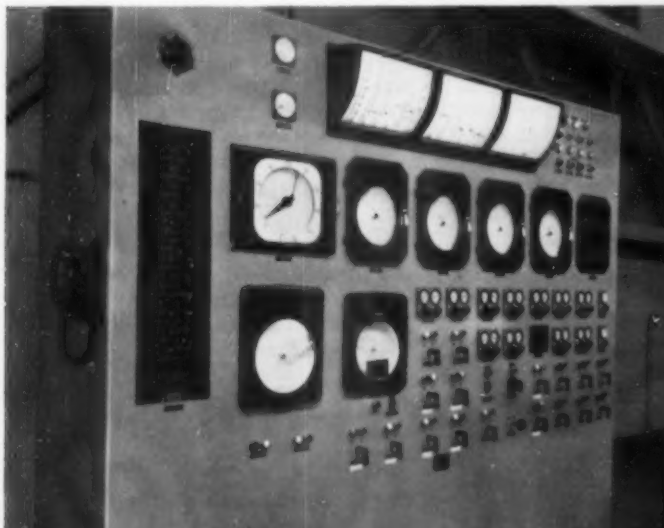
MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

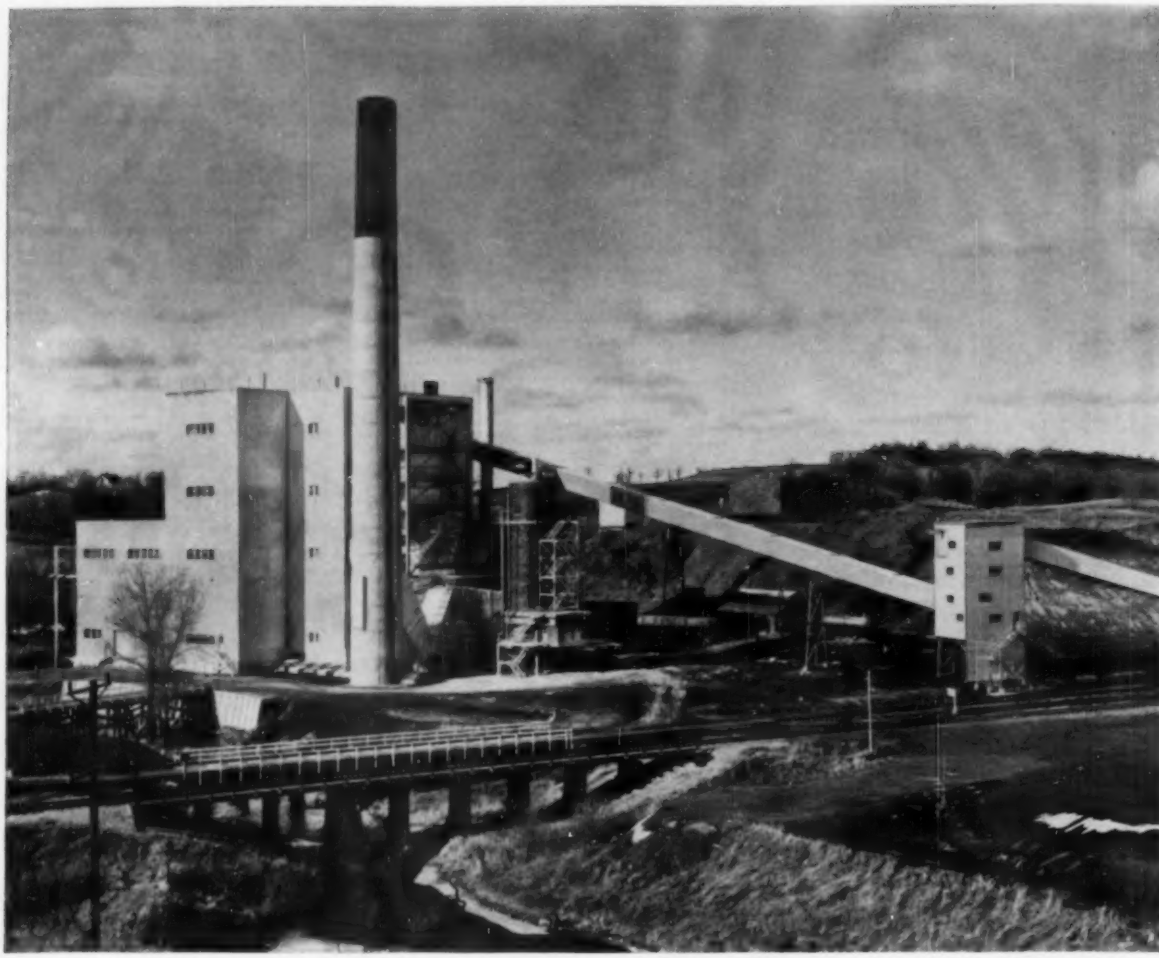


Except for the firing aisle and control room, Boiler Unit 7 is outdoors and subject to sub-zero temperatures. The unit delivers steam at 850 psig and 900°F to a 16,500-kw turbine-generator installed in the tall building (left) some 200 feet away.

Copes-Vulcan boiler control automatically balances output with demand at Taunton Plant



Eleven miniature Copes-Vulcan stations on this operating panel provide remote control of all processes with automatic-to-manual, or manual-to-automatic selection, with "bumpless" transfer. Automatic and manual loadings can be matched perfectly without going through a seal or reset position.



Rated at 53,500 kw, Hoot Lake is Otter Tail's newest station. The Otter Tail Power Company serves a 70,000 square mile area in Minnesota, North and South Dakota. Burns and Roe were consulting engineers.

MINNESOTA UNIT FIRES "WET" COAL

... Hoot Lake Station burns 1,000 tons of N.D. lignite daily

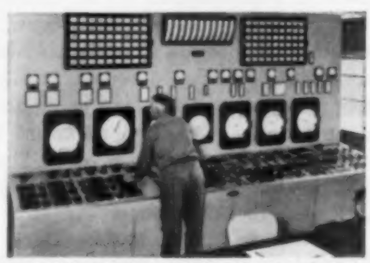
The Otter Tail Power Company's Hoot Lake Station at Fergus Falls, Minnesota, is the largest generating plant in the country burning North Dakota pulverized lignite. The steam generator is the first reheat unit to use lignite as the primary fuel.

Although lignite has a lower initial cost, its high moisture content (30-35%) and low heating value present unusual control problems.

After a year's operation, management is very satisfied with Hagan performance, particularly during several unscheduled outages, when the controls remained on automatic with excellent results. Hagan systems on the unit include combustion, 3-element drum-level, feed-pump, deaerating heater, forced, and induced draft fan control systems.

"Reasons for the selection of Hagan controls," one company official noted, "include satisfactory performance at our other stations, plus the high level of service and instruction provided by Hagan's Regional Service Engineer. We are pleased to have this same proficiency at our Hoot Lake Station."

Look to Hagan for sensible, workmanlike solutions to either special control problems or standard installations. A letter or phone call will put a Hagan engineer to work on your particular problem.



Control Panel at Hoot Lake. Hagan Ring Balance meters and the compact operating console make it easy for a single operator to maintain close control of the operation.

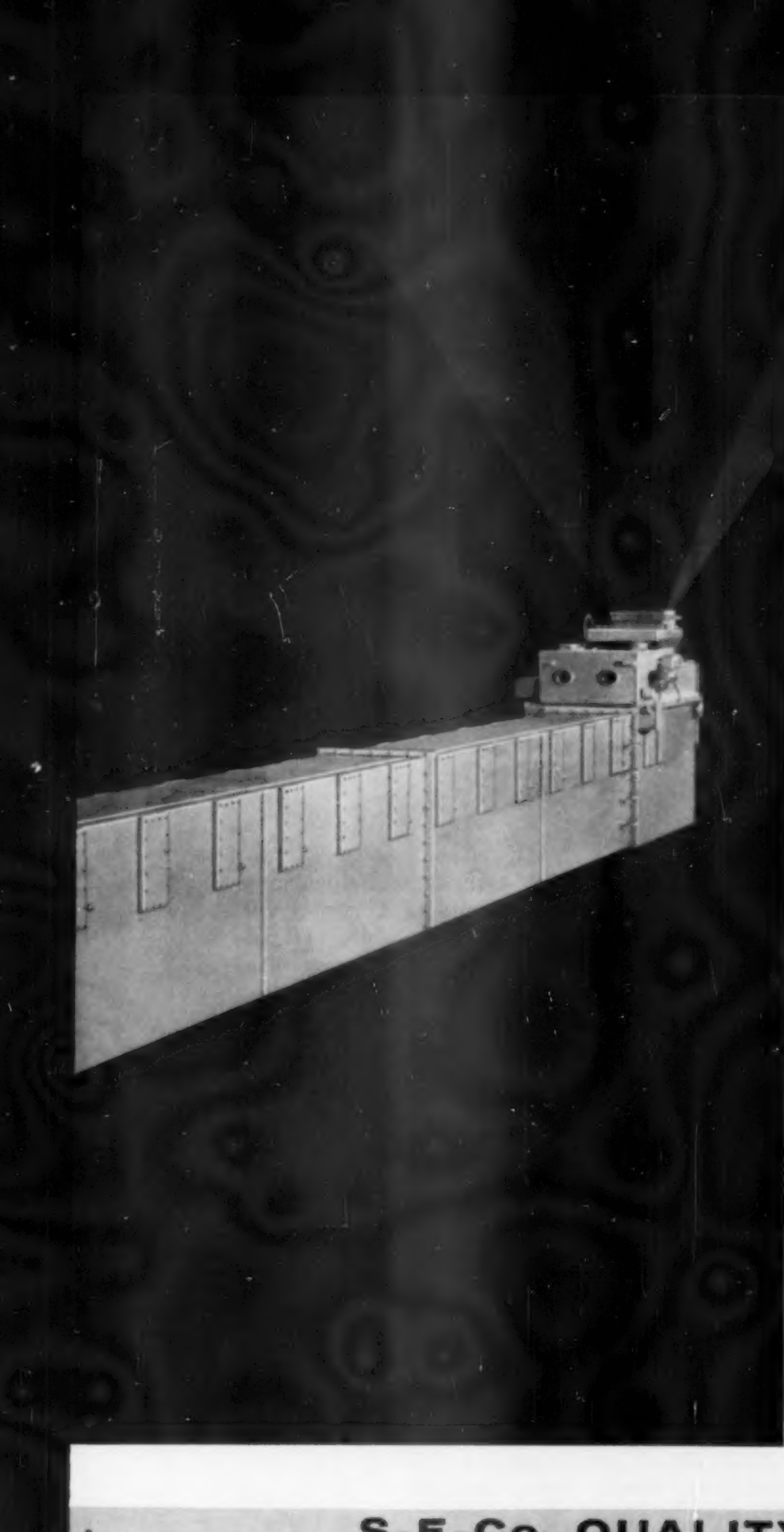
HAGAN

CHEMICALS & CONTROLS, INC.

HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO. • HALL LABORATORIES • BRUNER CORP.

POWELLFUL PERFORMANCE!
Powell pressure seal valves have been proved to control high temperatures and pressures in modern industries. More than 10,000 Powell pressure seal valves in installations on many continents have proved themselves to be precision-built, precision-tested, precision-performing.
This is just another example of Powell's unfailing quality as leading industrial valve supplier of the world. Let Powell's 115 years of valve manufacturing experience go to work for you.
So always look to Powell to solve your valve problems and fill your valve needs. Talk to the Powell valve distributor in your city. Or contact The Wm. Powell Company—TODAY!
115th year of manufacturing industrial valves for the free world
POWELL PRESSURE SEAL VALVES
THE WM. POWELL COMPANY · CINCINNATI 22, OHIO



STOCK EQUIPMENT COMPANY builds special volumetric and gravimetric feeders for pulverizers and cyclones. The feeder shown in the illustration is an L-shaped unit that carries coal approximately 65′ down the side of the boiler and then brings it in about 20′ to a cyclone burner. Units of this type allow a furnace to be fired from both the front and the rear and at the same time have a coal bunker on the front side only.

Feeders can be made almost any length and they can be double-decked, operated under vacuum or under pressure, and otherwise designed to suit requirements of purchaser's plant.

S-E-Co. Feeders are all equipped with endless rubber belts to assure maximum belt life and the best possible reliability. The width of the coal on the belt is 24″, and the feeder inlets are standard 24″ square or 24″ in diameter. This means fine, wet, sticky coal will feed with maximum reliability.

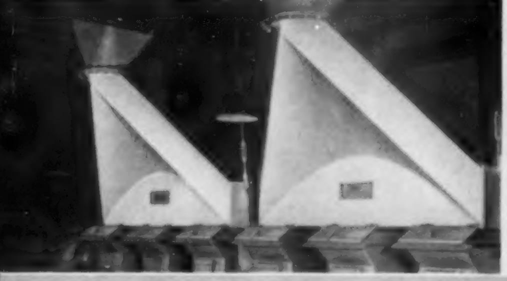
S-E-Co. Feeders are driven with a constant speed motor through a magnetic slip clutch to give the variable coal feed rate desired. A tachometer on the output shaft supplies a feedback signal into the motor control to balance the incoming signal and thus assure the feeder discharge rate corresponds exactly to the coal demand. There is nearly zero hysteresis in the system.

Send your problem feeder jobs to

STOCK EQUIPMENT COMPANY

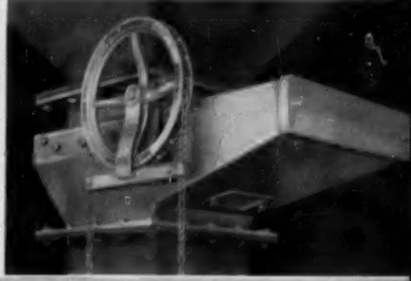
745 HANNA BLDG., CLEVELAND 15, OHIO

S-E-Co. QUALITY PRODUCTS

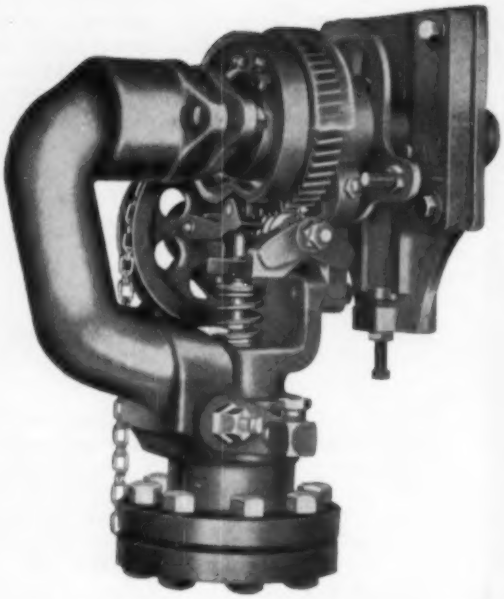


CONICAL NON-SEGREGATING COAL DISTRIBUTORS

COAL SCALES
Two Basic Sizes



COAL VALVES
6″ to 60″ – Many Styles



Quick Opening Bayer Soot Blower Valves Assure

- 100% cleaning efficiency
- minimum steam consumption
- superior high temperature resistance

The Bayer Balanced Valved Soot Blower is a single-chain operated design that assures precise sequential operation of the valve and element. *Only* after the start of full steam flow does element rotation commence—a feature which provides positive and efficient cleaning over the entire arc. . .without wasting steam.

The Bayer Soot Blower is simply operated by a pull on the chain which opens the cam-actuated valve. Continued pulling of the chain slowly rotates the element through its cleaning arc, at the end of which the valve automatically closes.

For severe high temperature locations, "super service" elements of Bayer-developed "Chronilloy" are available. Of superior strength, wrap-resistance, and stability, these elements resist the oxidation and chemical action caused by very high temperature gases.

In over fifty years of continuous specialized service, the Bayer company has equipped more than 35,000 boilers with dependable soot blowers. Engineered for long life and low maintenance, Bayer products assure economical and trouble-free operation.

ADVANTAGES OF THE BAYER BALANCED VALVED SOOT BLOWER

- single chain operation
- individual elements adjustable for high pressure service by orifice plate valve
- full steam pressure over entire cleaning arc
- selected gear ratios for optimum rate of element rotation
- minimum pressure drop through valve body
- machined air seal with spring loaded seat
- complete vacuum breaker protection
- precision swivel tube alignment lessens stuffing box packing needs
- load carried on ring type thrust bearings

For further information contact the Bayer representative nearest you. He is an experienced engineer, qualified to service Bayer Soot Blowers.

Agencies

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Philadelphia
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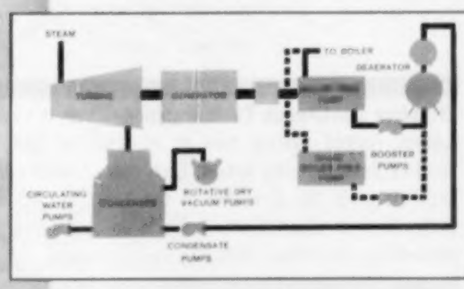
The BAYER COMPANY

4030 Chouteau Avenue, St. Louis 10, Missouri

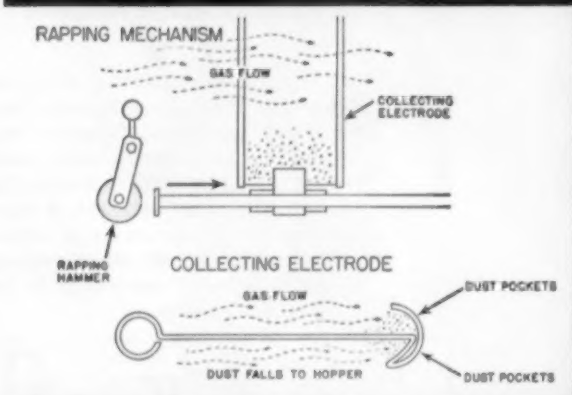


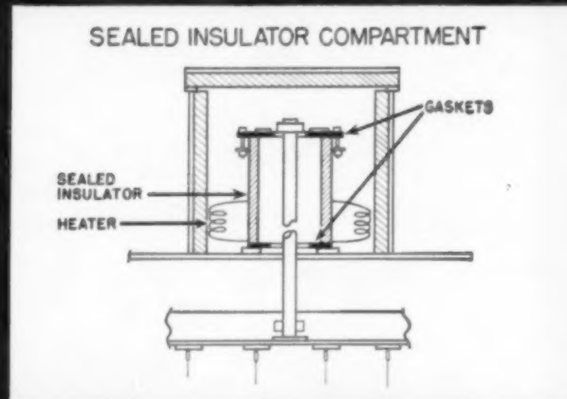
STEAM
TO BOILER
DEAERATOR
BOOSTER PUMPS
CIRCULATING WATER PUMPS
ROTATIVE DRY VACUUM PUMPS
CONDENSATE PUMPS

SOME PLAIN FACTS

ABOUT SUPERIOR PRECIPITATOR PERFORMANCE

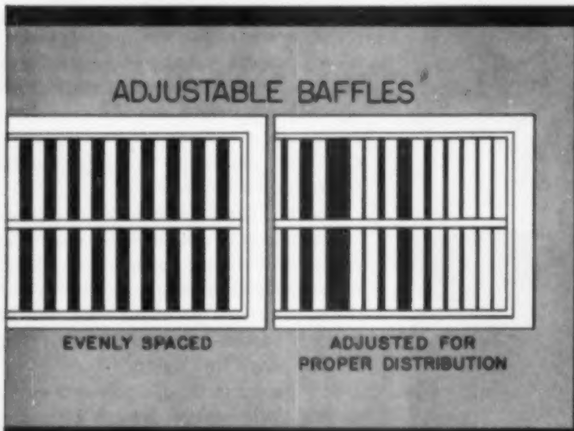
Buell Precipitators are designed and constructed for rugged service and superior performance. Frills and internal frim-fram of a doubtful value are eliminated in favor of strength and simplicity. The casing, outside supports, and internal parts are of rugged construction; and the four-point suspension of emitting electrodes ensures the greatest stability. Here are just a few of the outstanding features of Buell Precipitators.





Effective Continuous Cycle Rapping—Yes, it's mechanical. A simple, rugged system free of complicated gadgets; assures positive dust shearing action. Each row of electrodes is rapped separately—in the direction of the gas flow—on a continuous cycle. Dust is sheared off, drops in an agglomerated mass and pockets on electrodes minimize reentrainment.

Sealed Insulators Improves Operation—High voltage quartz support insulators are completely sealed; prevents gas and dust leaking into insulator compartment and outside air leaking into precipitator. There is no need for costly ventilating systems. Thermostatically controlled electric heaters insure start-up without danger of moisture condensation and insulator breakdown.



Uniform Distribution of Gas Flow—Field adjustment capability is vital. Buell's adjustable baffle permits final positioning after field measurement of actual flow distribution . . . because gas flow patterns are not entirely predictable. The Buell distribution system assures equal gas loading through the precipitator; eliminates ineffective "dead" areas around passages and prevents "sneak-by."

Buell Spiralectrodes cut maintenance to a minimum. Buell's record stands at less than 1% replacement in this key area. Self-tensioned spiralectrodes eliminate vibration and "off-center" swaying, often prevalent with weight-tensioned wires. They're structurally fixed and once installed stay in alignment. The spiralectrode provides greater emission than straight wires.

Buell precipitators are simple and effective. They're designed for continuous service. You'll be glad you turned to Buell when you experience superior performance and low maintenance. Detailed literature describing all features is available.

buell Norblo

The Buell Engineering Co., Inc., Dept. 70-B, 123 William Street, New York 38, N. Y. Northern Blower Division, 6413 Barberton Avenue., Cleveland, Ohio.
■Electric Precipitators ■Cyclones ■Bag Collectors ■Combination Systems ■Fans ■Classifiers.

Green Light Ahead?

Elsewhere in this issue one of the contributors comments, "It is always a risk to operate a power plant." This certainly is the philosophy under which most of the present operating and management executives of today's industrial and central station power plants grew up. The controls and the safeguards, now part of every day operation, were forced to run the gauntlet of why, how effective, what advantage, what limitation, what guarantee.

With the advent of the unit boiler-unit turbine and the subsequent rapid increase in unit sizes as equipment reliability proved out, the power plant man has found himself with more and more of his eggs in fewer baskets. He wants to protect himself better than he feels he now is. Yet his every instinct calls for any proffered protective device to meet the questioning of yesteryear. In this issue, pages 27–35, COMBUSTION publishes the first of a three-part verbatim discussion of Furnace Safeguards. Throughout this discussion we were keenly aware of the somewhat contrasting views of the operating man, the manufacturer and the consultant. Yet it is only from such public airings, such free give and take, that mutual understanding develops and the green light for progress can be seen ahead.

In line with this recognized and helpful give and take within the power industry we were delighted and disturbed at the same moment to have our attention called by several that our January Editorial on Automation omitted the projects of existing plants such as Public Service Electric and Gas Company of New Jersey's at Sewaren—all very much a part of the industry 's willingness to make the down payment for knowledge and advancement.

Alternate power sources for flame safeguard systems and the difficulty in switching from one source to another is a long standing operating problem. American Optical's Bernard Devine offers this solution.

By A. W. HINDENLANG

Associate Editor

Why Trip Safeguards to Switch Power Sources?

OUR HAT is off to Mr. B. W. Devine, Chief Engineer of American Optical Co.'s Power Plant at Southbridge, Mass. Reading in COMBUSTION of the difficulties experienced with boiler flame safeguard systems in areas where power failures are frequent, he did some original and constructive thinking. The results looked excellent to us.

The Problem

Most approved flame safeguard devices are by nature and by specification built to fail safe. Thus a holding circuit opened by a broken wire causes a safety shut-off valve to close—stopping the fuel supply to the burner. But when a system is designed to fail safe even a momentary power failure causes a complete shutdown of the boiler. True, a unit can be restarted immediately but explosion records prove overwhelmingly that starting-up accounts for 50 per cent of all furnace explosions. And when you start up on a crash basis to save a process or the plant load the probability of explosion skyrockets.

Some Previous Answers

Du Pont's Principal Power Engineer, M. L. Jones, summed up the situation in our Forum Report*:

"We've tried four auxiliary systems over a period of time. These are: steam-driven auxiliary generator, auxiliary generator connected to forced-draft fan with throw-over switching, inverter to convert d-c electricity from batteries to a-c for operation of safety equipment, convert all controls and valves from a-c to d-c.

"In the case of the auxiliary-driven generator, two units would be required, and if they are not properly maintained, reliability can be considerably less than public utility power.

"With fan driven generators the problem of maintenance is major in that the *generator requires a shutdown of the unit which is undesirable.* In addition, the *problem of throwover switching from purchased power to generator without a power failure requires momentary paralleling which is no simple electrical problem.*

"The inverter appears to be highly desirable in that existing standard units such as solenoid valves, relays and the like can be used. The problem is the procurement of a reasonably priced a-c to d-c to a-c power unit. Rotating equipment of this type is relatively expensive and requires a spare unit for reliability. The use of static converters and inverters with an auxiliary battery system for standby service appears to be a possibility.

"The newest seems to us to be the most attractive. Our first static converter (a-c to 26 v d-c) goes on a unit soon. We float a battery on the 26 v system connected to an inverter. We've tested its reactions to overloads, high voltage, other anticipated trouble points in the manufacturer's plant. It has a cut-off characteristic that lops off the tops of the sine wave. Yet we don't think it will trouble our instrumentation. We would like an electrical bypass so that we could pull out the inverter if it needs servicing. We're working on that aid right now. To use the battery is the most reliable system of power."

To COMBUSTION the simplest and least expensive solution seemed to be a small generator driven by the fan or boiler feed pump turbine. The flame safeguard system could be powered from this generator or could operate on plant power and be switched to the generator when the first storm or trouble signals came in. But in switching from one power source to the other a shutdown would be necessary since it is impossible to switch fast enough to prevent tripping the system. The two power sources could not be paralleled without the expense and complication of phasing equipment.

Devine Cracks a Tough Nut

Reader Devine remembered that most a-c coils will tolerate direct current for a time. He wired up his flame safeguard control panel as shown in Fig. 1 to take advantage of this tolerance for d-c. All that is required

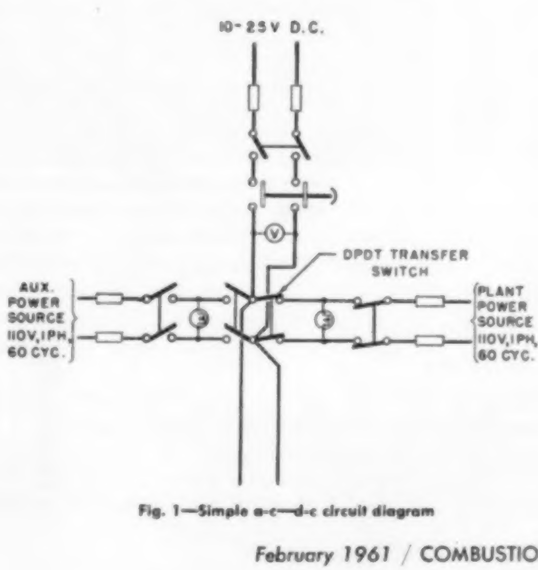


Fig. 1—Simple a-c—d-c circuit diagram

* "*The Combustion Engineering Industrial Power Forum*" March, April, 1960.

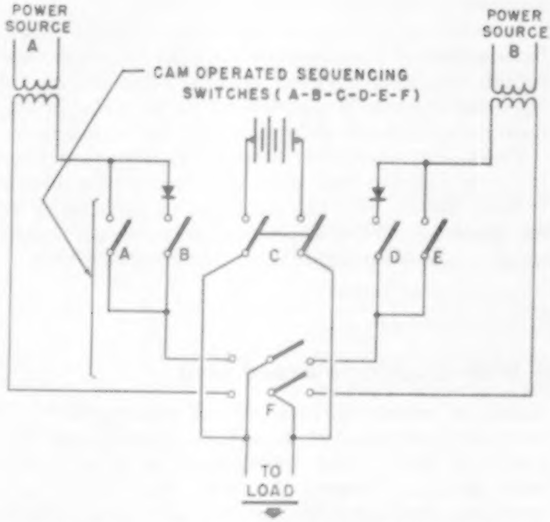


Fig. 2—Simple circuit modified by adding isolating transformers, diodes and sequencing switches

to switch power sources is to depress the pushbutton (applying 10–12 v d-c to the load) and throw the main switch. The idea is simplicity itself. It works in theory and could be applied to almost any system.

Setting up the system the first time, American Optical used a rheostat to vary the d-c voltage, seeking the optimum. On their four burner system it was found that 8 v d-c was the minimum hold-in voltage and 29 v. was the maximum. Impressing too high a d-c voltage cancelled out the a-c and relays dropped out immediately.

Furthermore it was found by experiment that the direct current flow was very high because the d-c tended to pick up as much of the available load as possible. One other difficulty was encountered during tests. It was found that every so often the system would fail and all relays drop out when the transfer attempt was made. It became apparent that the switch was being made at the precise point in the a-c cycle where the d-c voltage cancelled out the a-c.

Fig. 2 shows the cycle modification worked out to eliminate these two bugs. Isolating transformers (110 v/110 v) shown at power sources A and B prevented excess d-c current draw. Diodes installed above switches B and D furnished half wave a-c from the power source before d-c was impressed and prevented the troublesome "bucking" phenomenon.

To illustrate the sequence for switching from power source B to source A we start with switch E closed and F closed to power source B—open to source A. Then the sequence is:

1. Switch D is closed—load connected to full wave a-c from source B and half-wave a-c from source B through the diode.
2. Switch E opens—load connected to half-wave a-c from source B through diode.
3. Switch C closes—load on half-wave a-c and d-c from battery.
4. Switch D opens—load on d-c from battery only.
5. Switch F transfers—closed to power source A open to source B—load still connected only to d-c from battery.
6. Switch B closes—load on d-c from battery and half-wave a-c from source A.
7. Switch C opens—load on half-wave a-c only.
8. Switch A closes—load on half-wave a-c and full wave a-c from source A.
9. Switch B opens—load is now connected to full wave a-c from power source A.

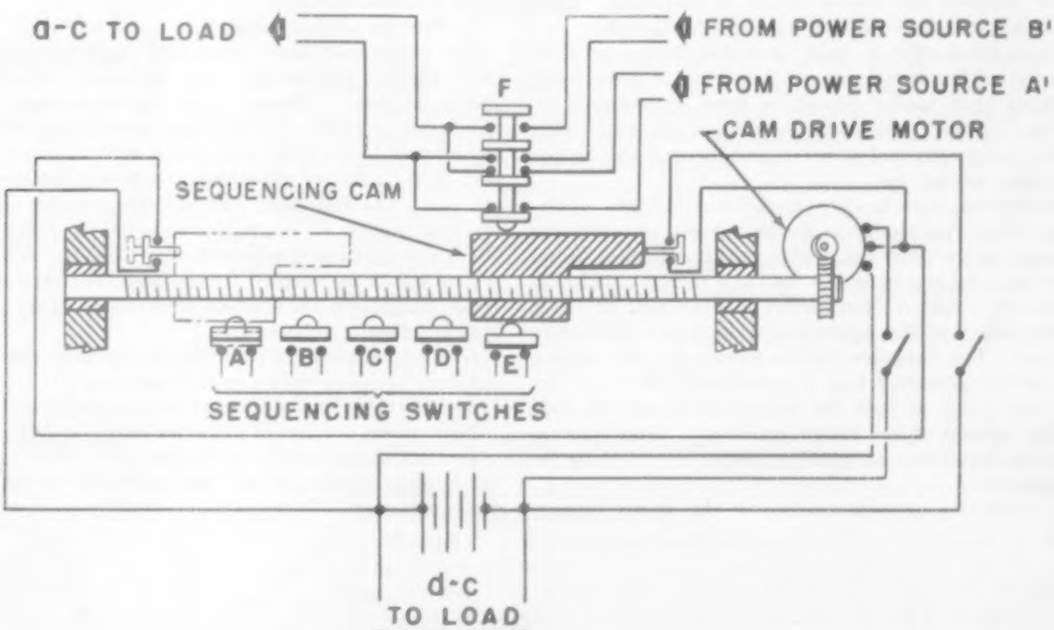


Fig. 3—Physical circuit arrangement showing sequencing cam and switches

This circuit, taken from American Optical's patent application drawings, is shown in more physical form in Fig. 3. Notice that the sequencing cam traveling on its threaded shaft completes the transfer from source B to A in one traverse from right to left. Limit switch stops cam at the end of its travel. Transfer from source A to B is made in one traverse from left to right.

The transfer could, of course, be carried out by a plunger or stepping switch if instant action were required. Obviously too, the device can be triggered manually or automatically by any of a number of signals such as drooping or increasing voltage.

It would seem a simple matter for manufacturers of flame safeguard systems to indicate the d-c requirements for safe switching of a given system so that battery voltage could be properly specified and the switching arrangement integrated with the system from the beginning.

Preliminary comments from some component manufacturers indicate that there may be considerable controversy arising from this solution to a particularly vexing problem. We will naturally welcome our readers' comments on this or other approaches to the problem.

Sporn Station Goes into Service With Duplicate Breed Unit

The second of the world's largest steam-electric generating units went into commercial operation December 31, 1960, at the Philip Sporn plant of the American Electric Power System. The 500,000-kw, $65-million unit of the Ohio Power Co. is the twin brother of the Michigan Electric Co.'s Breed Plant unit which went into service July 31 on the Wabash River in Indiana.

The Breed Plant unit is reported on in some detail in the *Electrical World* of January 16, 1961, and we note that it will be the subject of a full session at the forthcoming American Power Conference (see this issue COMBUSTION, p. 57).

The information *Electrical World* carried on Breed and which apparently holds for the Philip Sporn unit is that the boiler will operate at 3500 psi and 1050 F with two stages of reheat, both to 1050 F. This steam will go to a cross-compound turbine-generator consisting of two 3600 rpm cylinders exhausting into its own condenser. The Sporn unit is expected to have a heat rate close to 8500 Btu per kwhr which would make it the best ever for a unit operating on a commercial basis. Incidentally the Sporn generator stators are water-cooled whereas the Breed design is oil-cooled. Conventional hydrogen cooling is employed for the rotor.

The boiler design at Sporn undoubtedly has profited from the earlier experiences at Breed where it has been admitted that major difficulties were encountered at start-up. These difficulties, it is reported, have been satisfactorily corrected at Breed and the unit has met or exceeded expectations.

The transition from the conventional 2400 psi single-reheat drum type design of the manufacturer furnishing the unit to the 3500 psi double reheat selection Breed made revealed the necessity for (1) a forced circulation as against a natural circulation flow as well as (2) a redistribution in the apportioning of heat distribution surfaces. The designers further found that the furnace and burner geometry had a pronounced effect on the heat absorption at both the furnace level and the convection section of the steam generator. Recirculating gas they found was an excellent assist in correcting for imbalances.

A reported important feature of the Breed furnace design is membrane type of wall construction. The walls are constructed of shop-welded panels made up of 1-in. to 1 $^1/_8$-in. O.D. tubes spaced on $1^1/_2$-in. centers with the space between the tubes closed by a $^3/_{16}$-in.-thick bar, machine-welded to both sides of the adjacent tubes. This membrane construction has these declared advantages:

1—Part of the heat absorbed in the web is conducted to the rear of the tubes, permitting the back of the tubes to become heat transfer surfaces.

2—Raising metal temperature on the backs of the tubes reduces thermal stresses by reducing the temperature differentials through the wall.

3—Fluid mass-flow through the walls can be maintained at desired levels without using a large number of fluid passes.

4—Pressure-drop through the furnace circuits is less than it would be with tangent-tube construction because the fluid contacts less internal tube surface.

5—Weight of steel per sq ft of wall area is some 35 per cent less than for tangent tube walls.

6—Rigidity is greater than for a tangent tube wall using the same diameter.

7—Erection time is reduced.

The convection heat absorption section consists of three parallel gas passes. The secondary superheater and the economizer extend across the entire depth of the convection section. The first and second stage reheaters are located in separate gas passes and all but a small part of the primary superheater is located in the third gas pass. At full load, the gas temperature entering the first section of secondary superheater which is on 18-in. side spacing, is approximately 2200 F. A by-pass system has been designed for the boiler flow at start-up. While circulating the start-up flow, the by-pass system has the following functions:

1—Reduces pressure from above-critical in the steam generator to below-critical in the flash tank.

2—Provides a source of steam for the turbine seals.

3—Provides a source of steam for the generator.

4—Uses a large portion of the heat in the fluid entering the by-pass system to heat the feedwater in the high-pressure heaters.

The need for free and open discussion of the problems the steam-raising industry faces in controlling boiler furnace explosions prompted COMBUSTION to stage a forum on this subject a year ago (March, April 1960). This year this same forum treatment was staged under the auspices of the Fuels Div. of the ASME. First part of three.

Furnace Safeguards Panel—I*

In advance of the session all panel members were advised that the objectives were new ideas, untrammeled personal opinions— with the clear understanding that no comment by any individual would be construed as representing his company's policy and that no comment would be associated with an individual's name if he had any objection.

Purging

Chairman Summers.... "One of the best ways that I know of to start an argument on furnace safeguards is to consider, first of all, the subject of getting started. That brings to mind immediately the subject of purging. One of the panelists' questions was whether or not it was intelligent to use the time of this panel to discuss the question of purging since he said that anyone who has ever operated a unit must have solved that problem thirty-five years ago.

"I know many of our clients have operated units for more than that length of time and *in toto* I don't believe we have all solved that problem. I would like to start off with the question that probably is the basis of safe light-off, and that is the question of purging: When, how, and how do you know you have done it properly?

"I think one of the people that should be put on the spot first with this is Brother Livingston."

W. L. Livingston.... "The questions are how, when, and I would like to start off with answering why. We feel that the right thing to do is to differentiate between a regular start-up purge and a purge that is required after a safety shutdown when something has gone wrong.

"We feel that in the present state of the art, it is pretty tough to determine just why you have lost the fire on a safety shutdown. We feel that since we don't know why in most cases we have lost the fire, we should have additional purges for a safety shutdown as opposed to a normal shutdown purge."

* Presented before the Annual Meeting of the ASME, New York, N. Y., Nov. 28, 1960. No formal paper number assigned.

THE SCHEDULED PANEL

Chairman: **W. A. Summers,** Mech. Engr., Ebasco Services, Inc.
Vice-Chairman: **A. W. Hindenlang,** Technical Editor, Combustion Engineering, Inc.

J. U. Baley, Asst. Gen. Supt., Electric Operations, Baltimore Gas & Electric Co.
William C. Beattie, Asst. Vice-Pres. of Electric & Gas Production, Consolidated Edison Co. of New York, Inc.
L. H. Coykendall, Field Engrg. Coordinator, The Babcock & Wilcox Co., Boiler Div.
V. F. Estcourt, Mgr., Steam Generation Dept., Pacific Gas & Electric Co.
C. W. Kellstedt, Production Supt., Production Dept., Consolidated Edison Co. of New York, Inc.
W. L. Livingston, Burner Group Leader, Kreisinger Development Lab., Combustion Engineering, Inc.
R. M. Lundberg, Efficiency Engr., Commonwealth Edison Co.
E. R. Mitchell, Head, Combustion Research Section, Fuels & Mining Practice Div., Mine-Branch, Dept. of Mines & Technical Surveys, Ottawa, Ontario, Canada
C. E. Parker, Asst. Genl. Supt. of Generation, Public Service Electric & Gas Co.
R. I. Wheater, Chief Proposal Engr., Steam Dept, Foster Wheeler Corp.

UNSCHEDULED PARTICIPANTS

Russel R. Beal, Bailey Meter Co.
Charles D. Birget, Commonwealth Associates
L. F. Deming, U. S. Bureau of Yards and Docks
M. D. Engle, Pennsylvania Power & Light Co.
J. C. Falkner, Copes Vulcan Div. of Blaw-Knox
Paul Grossman, Combustion Power & Equipment Ltd., Montreal
W. T. Reid, Battelle Institute
Temple Voorheis, Coen Burner Co.

Chairman Summers. . . . "What kind? In other words, are you proposing higher air flows, lower air flows?"

W. L. Livingston. . . . "That is right. We are definitely advocating a higher length and quantity of purge for safety shutdown than for a normal shutdown. After all, if you have a normal shutdown, you shouldn't theoretically have to purge at all."

Chairman Summers. . . . "What about the old worry that an excessively high rate of purge might actually break loose pockets of unburned combustibles and create an explosion?"

W. L. Livingston. . . . "This, of course, is true. However, you have to balance the whole thing out. You have to take the risk of whether you are going to purge out these pockets to begin with or leave the pockets there and perhaps subsequently ignite them after you have put the fire out in the furnace."

Chairman Summers. . . . "Don't you feel that you can ease them out by a gradual, let us say, increase in air flow, chewing away at them little by little?"

W. L. Livingston. . . . "If you have eased them out, then you have in effect purged them out. You are trying to differentiate between an easy purge and a hard purge?"

Chairman Summers. . . . "Yes, very definitely."

W. L. Livingston. . . . "This is pretty tough to do on a scientific basis."

W. T. Reid. . . . "Mr. Chairman, how about definitions? I would like to know about

definitions. When we are talking about purges, it means one thing in one person's mind and another thing in another's. To a physician this is something different. (Laughter). How about a definition so we know what we are talking about?"

L. H. Coykendall....

"I might say that we have advocated for many years 25 per cent of full-load air flow as measured by the air flow meter at room temperature, for five minutes. We have no instance where this has caused an explosion.

"You have to be careful of this. This is for a start-up purge before you do anything on starting up a cold boiler.

"I disagree somewhat with Mr. Livingston's idea that you should increase the purge after a flameout.

"Our instructions, which to our knowledge have been satisfactory, say that you should not change the air flow on the flameout; trip the fuel; leave the air flow alone, and after things have steadied out somewhat, slowly reduce the air flow. This is sort of a definition of what we call a furnace purge.

"Twenty-five per cent of the full-load air flow for five minutes corresponds very closely to what the insurance people have been advocating for many years of four volume changes. If you calculate the retention time throughout the unit, it will vary on Babcock & Wilcox boilers—at least I have checked this—from four volume changes to as high as six or seven volume changes in the boiler."

Chairman Summers....

"Mr. Wheater, would you care to comment on this?"

R. I. Wheater....

"We are generally in agreement with the last statement. We normally advocate a 50 per cent purge for about five minutes for a purge prior to lighting-off. In so far as purge after a safety shutdown, we would consider the same."

William C. Beattie....

"I would like to state this. We are using the word 'purge,' and I would like to agree with Mr. Reid. What is a purge? When do you accomplish the purge? What is the end point that says you now have a purge?

"We are told by Mr. Coykendall about four times the volume. That seems to me to be a rule of thumb which custom and practice has dictated, that over the years you can get by with it. You can go to five times the purge, but, as we now sit in the power plant, the operator doesn't know when he has hit the end point of the flow going through the passes and the boiler, so that he now has accomplished this so-called term 'purge.'

"It seems to me that we ought to face those facts. You can use the word 'purge.' You can use the quantities of gases, and you can use any method you wish, but when do you get to the end point so that you can tell the operator in this particular furnace volume he has accomplished this purge?"

C. W. Kellstedt....

"Mr. Chairman, wouldn't this be a good place to have a discussion on the combustibles meter and its function in this respect?"

Chairman Summers....

"Let us hold that off. I think Mr. Livingston has a comment, and I am pretty sure Mr. Parker has a comment on the matter of purging."

W. L. Livingston....

"I would like to recall back to the previous session held in Atlantic City where the question of purge was brought up then. (Editor's Note: March, April, 1960 COMBUSTION) Mr. J. B. Smith said, "With four successive air changes you would have diluted the original volume of air and gas down to $6^1/_2$ per cent of whatever the original saturation may have been."

"Six-and-a-half per cent of fuel in air is for most gases, especially natural

gas and air, right within the flammable mixture.

"When you say that your system of purging a furnace will be equivalent to four air changes, you are saying in effect that if your original furnace volume was filled with fuel, you have created an explosive charge out of a charge that was to begin with not explosive."

W. C. Beattie....

"That is provided there is no hideout, the velocities of the scavenging air flow, if you want to term it that, or the gas flow through the boiler actually scavenged all the caverns, the corners of the furnace that you are dealing with or the boiler box itself."

Chairman Summers....

"Mr. Parker, would you care to comment on that from the operating end?"

C. E. Parker....

"We do it from a very scientific standpoint. B&W recommends five minutes. We figure it wouldn't do any harm to purge for ten minutes and, therefore, we recommend fifteen. In addition to that, we have recently installed combustible meters, and we believe them to be accurate.

"We would not start the fire, even after fifteen minutes if any combustible is left on the meter."

Chairman Summers....

"This, of course, presumes that the sample going to the combustible meter represents the worst pocket in the boiler."

C. E. Parker....

"In any case, we have gotten three times the recommended amount of purging."

Chairman Summers....

"Are there any other panel members that would like to comment on this before we move into some discussions on the combustible meter?"

R. I. Wheater....

"I would like to ask Mr. Livingston a question. In his comment about a rich furnace, if you don't purge, how do you eliminate the gas from the furnace?"

W. L. Livingston....

"Of course, with the present hardware we have today—and we hope we have the answer in this inner purging system—you have to acknowledge that you can't avoid the limits of inflammability. It is something like fighting bulls. You have this moment of truth where you are adding air, and this fuel-air ratio is going down, and it goes through all the limits of inflammability.

"We suggest that you try to go through these limits with the lowest amount of flow to the furnace possible. Either way, we wish you the best of luck." (Laughter)

Chairman Summers....

"I presume you also mean with the minimum source of ignition?"

W. L. Livingston....

"Yes, sir."

L. H. Coykendall....

"Mr. Chairman, I think that Mr. Livingston is doing excellent work in developing the basic theory on how explosions occur. However, most of this so far is based on his thinking of a closed vessel without a dynamic flow-through, which you very seldom have in the boiler.

"This means that in a large volume of combustible gas, you must mix air all through that volume in order to get an explosive mixture. If this vol-

ume of gas is flowing, a good part of the gas is flowing out of the boiler. That is, when you begin introducing air at a low rate and bring it up to 25 per cent, if there was a 100 per cent combustible gas atmosphere, natural gas for instance, this gas would be gradually flowing on out of the stack and you would mix air with only a small volume of the gas. I believe that in the development of this theory, the thinking is necessarily based on a closed vessel, without flow, where you mix everything all at once. With a flowing system, it is impossible to mix throughout and this is the difficulty with introduction of an inert gas.

"If you are in a rich atmosphere, and flameout, and do not shut off your fuel but try to introduce an inert gas, this inert gas is not going to mix with all of the fuel that you have put in before you started to introduce it or until you have built up the volume of the inert gas that will prevent an explosion.

"Therefore, my way of thinking is that the minute you lose ignition at a burner, you should cut off the fuel, regardless of whether it is a fuel-rich or an air-rich mixture in the furnace."

Chairman Summers.... "That is at a single burner?"

L. H. Coykendall.... "This is a single burner or complete flameout of all the burners on the boiler at one time, which very seldom happens at high load, but very often happens at start-up load."

Chairman Summers.... "I would like to pose a question to the panel and just ask them to answer by raising their hands. Is there general agreement that a boiler, which is permitted to get in a condition of heavy excess of fuel, let us say, one that is at the point where it is non-explosible because it just got too much fuel, or one that is in the explosible range because it has too much fuel, that there is today no practical way to shut that boiler down safely? Do you agree or do you disagree? Raise your hands if you agree. We have eight versus three."

L. H. Coykendall.... "I disagree with that."

Chairman Summers.... "We haven't heard from Mr. Estcourt. You didn't raise your hand. Could you advise us what you think is the safe way to shut down a boiler under those circumstances?"

V. F. Estcourt.... "I had the pleasure of doing it about twenty-eight years ago. I think it can be done, not by tripping off the burners, however.

"The only way you can do it with minimum risk is to gradually reduce the fuel until you finally re-establish a safe condition."

Chairman Summers.... "Leaving the air as it was?"

V. F. Estcourt.... "Leaving the air as it was, yes. I know this can be done, because when I was a small boy, more or less, when we got into our first high pressure reheat unit, which was one of the earliest ones in the United States, we had a fireman who, although one of the best-educated men on the job, didn't think very fast on his feet. I had to go down and get the boiler out of this mess.

"As testimony that it is a ticklish job, there was evidence of secondary combustion going on during the process of reducing the fuel, but it never got to a point where it reached explosive proportions, but where rumblings did become audible in the reheater section of the job. It was a case of feeling one's way down at a slow enough rate."

Chairman Summers.... "Couldn't you attribute that also to just good luck with you that day?"

Mr. Estcourt... "No, I don't think so at all. I don't think there is any luck about it. If you don't believe it, I suggest some of you try tripping the fuel off and see what happens."

C. E. Parker.... "That makes Mr. Estcourt in agreement with the rest of us. That is not shutting the boiler down. He is correcting the boiler."

L. H. Coykendall.... "I still am in disagreement somewhat. I agree with Mr. Estcourt's way of taking this out while you still have a fire in the unit. This is what a good operator should do, and it is a very good way of bringing the unit out of this fuel-rich mixture.

"You must remember, so long as you are in that fuel-rich mixture, and you have a fire, it cannot explode.

"As Mr. Livingston has shown in his several papers, you cannot get an explosive mixture."

Chairman Summers.... "We will have to cut this off. We have already devoted four minutes beyond our limit."

A. W. Hindenlang.... "Before we leave the subject of purging, number one, we have a pretty general disagreement on what boiler catharsis consists of. There is no definition. I wonder, first, if anyone on the panel could volunteer where we are going to get a definition of what constitutes a positive purge and when we should do it?

"Some of the gentlemen feel in some cases the purge is the worst thing we can apply. As we leave the subject gracefully, it seems like the next logical point might be when do we trip?"

Chairman Summers.... "I think that is a good point. I would like to try and summarize this right now. I feel there is a definition of a purge, and I think it is a simple one. It is obviously when you have changed the boiler chemical constituents to a point when you can safely light a fire.

"The next one is not quite so easy, and that is defining this in terms of measurement hardware.

"We are going to come to some discussion in a few moments on combustible meters, which is certainly a mechanism—if the sampling systems can be designed—that could tell you when it was safe to light a fire.

"I think if we can leave this subject on that point, we do not have agreement, and we have roughly an eight-to-three split on the one subject. I think we can get a unanimity on the fact that if you lose your fires in an air-rich or on a lean mixture, is there a safe operating action such as tripping the fuel? Will everyone raise their hands if they agree that is a safe thing to do? Look well! You will probably not see the rest of the afternoon everyone raising their hands."

V. F. Estcourt.... "I would like to ask in relation to your question what is it you are tripping for under the circumstances that you described?"

Chairman Summers.... "I think I said flameout; so, therefore, you want to stop the introduction of further fuel to prevent yourself from getting rich."

V. F. Estcourt.... "I assume that you are thinking rather of just a few burners in the boiler."

Chairman Summers.... "Let us say so."

V. F. Estcourt.... "During the initial start?"

L. H. Coykendall.... "Or perhaps all of them."

Combustible Meter Detectors

Chairman Summers.... "The next point I think that we should spend a few minutes on—and I will hold this to about five or seven—is thoughts on the use of combustible meter detectors. I think we will go to Mr. Coykendall for the first comment on this subject."

L. H. Coykendall.... "We are slipping way over. I think Charlie Parker has the right slant on this. I believe we should make more use of oxygen analyzers and combustible recorders, even to go so far as to trip under load conditions with the combustible recorder, so you do not get into this overrich mixture. Mr. Livingston, I believe, has shown that you must burn less than 36 per cent of the fuel that you are introducing into the furnace in order to have an explosive mixture if you trip. If you use your combustible analyzer to trip the unit before the deficiency of air has reached this level, you are safe, and you can trip the fuel, and you can add all the air you want, and it won't explode."

Chairman Summers.... "In other words, you are advocating protective tripping prior to the rich mixture?"

L. H. Coykendall.... "That is right. I think we need more of this.

"There is another way it might be done, and that is to use some of the better combustion controls which have a fuel-air ratio control and automatic fuel cut-back. This control system could be adapted to sound an alarm if the fuel-air ratio deviates from a specified band, and to trip the unit if an unsafe ratio is approached. I think that if we set up the combustible recorder to alarm at 1 per cent combustibles, which is still a safe condition, and then if that condition were maintained for five minutes, the unit would trip, this should give the operator at the controls time to recover and bring it back gradually, as Mr. Estcourt did with his, by hand. But then if it reached 2 per cent combustibles, I think we should have it set to trip in 30 seconds; or if we reached a total of 3 per cent combustibles, it should trip right now. You still are in a non-explosive range, according to all the theory. I believe that agrees with you, Mr. Livingston."

W. L. Livingston.... "I would advocate developing the combustibles recorder and using it as a method of preventing you from getting the fuel-rich mixtures in the furnace that can be explosive later on, if there is a flameout, or if you trip at a later time."

Chairman Summers.... "Mr. Baley, your people have been doing some thinking on this subject. Do you have any comments?"

J. U. Baley.... "I would like to ask Coy what he does about time lag on the combustible meters. I think by the time the combustible meter will trip the boiler, he might not have a boiler."

L. H. Coykendall.... "I have looked into that a little bit. The combustibles recorder can be

set up, close-coupled to the boiler, and with solid-state amplification, so that with a 12-foot probe and 25-foot sample line to the recorder, you will get an indication of the combustibles in the unit at the point you are measuring in 15 seconds. If you reach 1 per cent in 15 seconds, and you keep it for three minutes at that level, you are still okay. If it increased to 2 per cent, and you went for 30 seconds, that would mean a total of 45 seconds from when the condition started, and you would still be safe."

Chairman Summers.... "Actually, faced with practical problems of sampling systems, that would mean maybe a dozen combustible recorders on individual points because it means you average these things. You may have combustibles in one section and not in the other, and you could dilute considerably the very thing you are trying to find."

J. U. Baley.... "I am sure the combustible meter may give more information to the operator along with indications of individual fires by flame detectors—and steam flow-air flow indication—but I don't think you can solve the problem by taking the responsibility away from the operator. If you give him more information as to what is going on, that is fine."

V. F. Estcourt.... "Are you talking about these combustible indicators tripping the boiler in the case of unattended boilers or is there an operator there?"

Chairman Summers.... "This panel is certainly not aimed at unattended boilers. Let us say it is with an operator there."

V. F. Estcourt.... "You would do a lot better if you fire the operator."

W. L. Livingston.... "You can't fire him fast enough."

V. F. Estcourt.... "I am a little bit surprised that we have to do all this talking about such things as combustible indicators. We have had them for more than a quarter of a century in our plant. I can't quite imagine operating a large power boiler without a combustible indicator.

"We long since did two things. One was the combustible indicator, and the other was to lock out the combustion control, so that the fuel will not increase, and the air cannot decrease in case of the presence of combustibles.

"It seems to me that that should be adequate to take care of it. It has been adequate in our case."

W. C. Beattie.... "How do you take care of a tripout on the fan, on a lockout?"

V. F. Estcourt.... "You say if a fan happened to trip out, all at the same time?"

W. C. Beattie.... "No, just if it tripped out; never mind the same time. If the fan trips out, how does the lockout take care of the fuel-air ratio?"

V. F. Estcourt.... "It is tripped automatically."

W. C. Beattie.... "To the level where it would be done instantly?"

V. F. Estcourt.... "Yes."

Mr. Russel R. Beal.... "I think we are all in agreement that combustibles will play an important part in any interlocking circuit that is devised. However, these devices do have their limitations, and I don't believe there has been any definition by the panel as to what fuel is being considered in this discussion of interlocking circuits.

"Obviously, if it is gas, there isn't too much of a problem of obtaining an analysis, but if you are talking about oil or coal, there must be heat in the furnace before it can be analyzed for combustibles.

"Therefore, we feel that any measurement of combustibles should be interlocked with some device, such as a flame monitor or some thermal device, before it becomes a satisfactory type of interlock."

Chairman Summers.... "Therefore, it is not satisfactory on starting up a coal furnace, let us say?"

R. R. Beal.... "That would be true if you have a coal furnace with insufficient temperature to produce volatiles from such fuels as coal or oil. With coal or oil it wouldn't be a satisfactory device."

Chairman Summers.... "Yet some of them could be left over from shutdown."

R. R. Beal.... "This is true if you are talking about shutdown."

Chairman Summers.... "Mr. Livingston wanted to have a word on this subject. Then we will abandon it."

W. L. Livingston.... "Let us assume for a minute that we did have a fool-proof, flawless method of analyzing furnace gases. There is little argument that such a device could be applied to a furnace as a protecting system. Certainly it could.

"The problem of applying this thing, of course, is secondary. What do you do with it after you have got it? Whereas you might not have much argument on applying the device, I am ready to fight now as to where you are going to set that device to trip. Certainly 1 per cent combustible or 100 per cent combustible is absolutely no guarantee of whether you have an explosive mixture in the furnace or not. If is only part of it. By itself it is meaningless.

"You have to compare both the per cent of fuel and the per cent of oxygen and the per cent of inert and what kind of inert. It is all at the same time necessary to determine whether your mixture is explosive or not.

"Certainly 1 per cent combustibles or 2 per cent or 3 per cent is not general enough to say that this is going to lead to a problem or not. By itself it is meaningless. It always has been."

Correction Notice:

C. C. Shale, co-author, of the article "Precipitators in New Operating Range" which we ran in December 1960, pp. 42–43, has called our attention to three errors appearing in the publication.

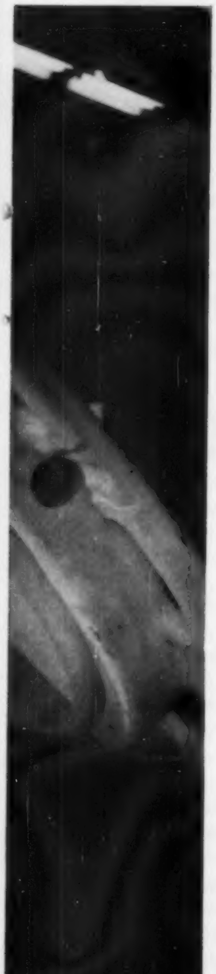
(1) The summary, Mr. Shale points out, is incorrect in that industry **does** *use precipitators at temperatures above 1000 F and secondly the authors made no statements on removal above 1200 F.*

(2) The abbreviation the authors employed of feed rates "from 2 to 4000 g per hr" was to represent grams and not grains as the published article reported.

(3) In Fig. 1 as reprocessed there are three misspelled words—"elutriator," "sampling" and "sight."

How Edward Valve Research

Reduced Pressure Drop 70%



Power industry advances in unit size created a need for large, high pressure steel valves (ten inch size and larger, 1500 lb class and higher) with three basic qualities: 1. Permanent tight seating; 2. Capacity to handle high flow rates being encountered in new, high pressure plants; 3. Reduced downtime through simplified maintenance. Edward researchers developed the Flite-Flow* design to satisfy that need. This is their story.

In 1951 Edward had already developed large cast steel globe valves with excellent dependability and repairability. Long experience in building inclined stem Y-type valves in small sizes indicated that this configuration offered a more efficient flow path. Edward research engineers set out to learn whether sufficiently strong pressure containing structures might be built in the Y-type design in larger sizes. They also sought to find out if pressure drop could be reduced sufficiently to make such a valve practical for high pressure power plant services.

The project consisted of three steps:

1. INTERNAL CONTOUR DESIGN—Flow tests were conducted with a series of plastic models. Early in the testing program it was observed that flow capacity was not always directly related to the size of the opening. Reduction of turbulence proved to be even more important. This eventually led to subtle internal contour changes to pre-shape the flow before passing through the valve seat. More material was added to certain internal areas to gain additional structural strength.

2. DISK GUIDING TESTS—To compensate for the angular position of the stem-disk assembly tests were conducted to determine whether conventional three-point guiding used in vertical stem Edward valves would be adequate for the inclined stem design. Experiments suggested that four equally spaced guiding surfaces would be superior. This is important in floating disk types such as check or stop-check valves where disk-piston assembly must seat automatically.

*T.M. Reg. U.S. Pat. Off.

3. STRUCTURAL STRENGTH—The usual weakness of a Y-type pressure containing vessel received much attention. Optimum valve contour as determined by flow testing permitted use of a structural member in the flow passage at the downstream side of the seat port. This structural member provides strength exactly where needed without significant increase in pressure drop. Introduction of this segment to the valve body casting without sacrifice in pressure drop was a significant achievement.

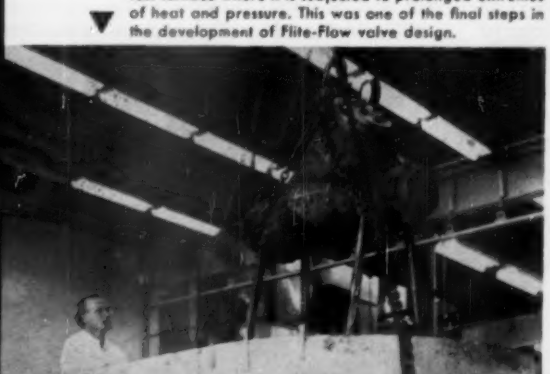
RESULTS: This program covered a period of six years. Tests of the completed design were most gratifying. Structural stability, a major problem, was excellent. Strain gage and brittle lacquer tests of finished valve bodies showed stresses well within acceptable limits. Pressure drop reduction amounted to as much as 70 per cent from best previous globe valve experience. Extended tests of finished product at pressures and temperatures above rating showed no operating weaknesses. The Flite-Flow is truly a dependable, repairable, low pressure drop valve.

Edward builds a complete line of forged and cast steel valves from ¼" to 24" for industrial, marine, petroleum and technological services. For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

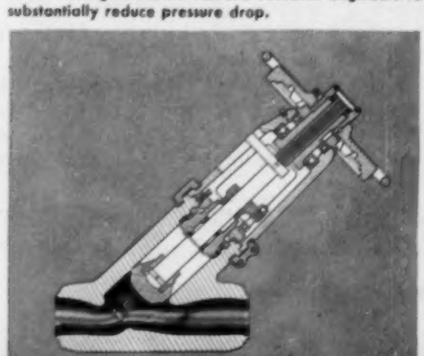
EDWARD STEEL VALVES
another fine product by
ROCKWELL

◀ W. G. Lunt, research engineer, and E. B. Pool, chief research engineer, study flow phenomena in plastic half-model of tentative Flite-Flow design.

Edward research team lowers experimental valve into test furnace where it is subjected to prolonged extremes of heat and pressure. This was one of the final steps in the development of Flite-Flow valve design. ▼



Cutaway view of Flite-Flow valve showing how inclined stem Y-type valve configuration has been adapted to larger size units for power plant services. This internal contour design enabled Edward research engineers to substantially reduce pressure drop.



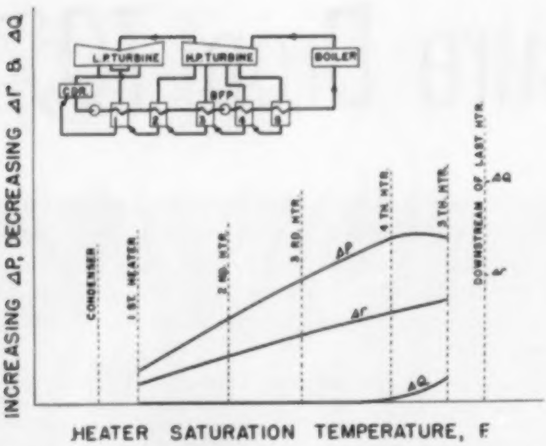


Fig. 1—Thermodynamic effects of a main unit variation of 10 million Btu/hr on a 60 mw cycle, throttle conditions 850 psig, 900 F.

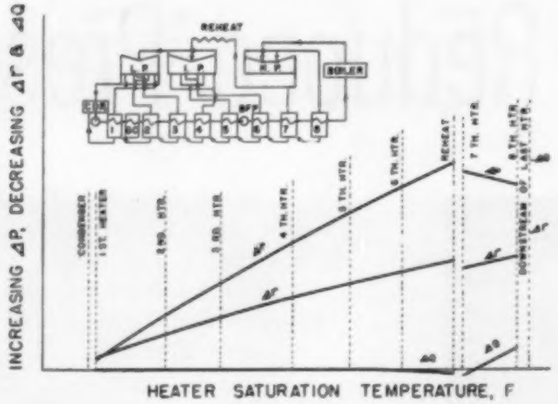


Fig. 2.—Thermodynamic effects of a main unit variation of 50 million Btu/hr on a 300 mw cycle, throttle conditions 2400 psig, 1050 F, reheat to 1000 F.

Optimizing a Regenerative Steam Turbine Cycle*

By G. CHIANTORE† D. BORGESE† F. BALDO† and J. H. POTTER‡

Edisonvolta, S.p.A. Gibbs & Hill

Conventional design procedures require complete and accurate heat balances on each of a number of alternative regenerative cycles in order to determine the optimum cycle for a given set of conditions. This paper presents an analytical method to reduce the number of heat balances required and yet optimize the cycle.

THE SELECTION of the best steam turbine regenerative cycle for a new power installation is normally determined by heat balance studies of several alternative arrangements. The complexity of modern steam power cycles is reflected in the heat balances, and a great amount of time must be spent in the conventional heat balance comparisons of the alternatives. As a result, many efforts have been made to set-up rapid or shortcut methods for arriving at the optimum cycle (1–8).[1]

This paper reports upon an analytical design method developed at the Edisonvolta, S.p.A., Milan, Italy, in which a minimum number of heat balances are required for the optimization of the feedwater heater system. The method involves the analysis of a "basic" cycle, decided upon by the utility management and the manufacturer, as being appropriate for the installation. This implies a selection of the turbine, at least as far as capacity and steam conditions are concerned, and the estimated locations of the bleed points. The basic cycle *is not* a generalized or simplified or fictitious cycle: building the method upon a generalized cycle would reduce the accuracy of the results to the degree obtainable with the present shortcut methods. Each case must be referred to a basic cycle involving only the specified capacity and steam conditions for that particular installation. It assumes that the alternatives to the base cycle may produce more or less power, cost more or less money, and operate at rated load at a greater or lower heat rate than the base cycle. When these alternatives are compared to the base cycle, it further assumes that for evaluating purposes:

(*a*) Each unit of power generated can be used; each unit of power missing could have been used; each unit of power will have the same value and will be capitalized in the same way.

(*b*) The change in heat rate will be capitalized, taking account of the probable fuel cost changes and the probable plant capacity factor over the life of the installation.

(*c*) The incremental equipment costs of the alternatives will be algebraically added.

If the turbine described in the manufacturer's proposal is still in the preliminary design stages, a study can be made to fix the number and location of the bleed points and, consequently, the final feedwater temperature. If the proposed turbine has been fully designed, the only possible investigation is the determination of the feasibility of the turbine load changes, and the economics of

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Paper No. 60-WA-179.

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[1] Numbers in parentheses identify references listed in the Bibliography.

NOMENCLATURE

P_b = power of the basic cycle, kw
r_b = heat rate of the basic cycle, Btu/kwhr
= Q_b/P_b
Q_b = heat furnished by the boiler in the basic cycle, Btu/hr
ΔP = change in turbine capacity, kw
Δr = change in heat rate, Btu/kwhr
ΔQ = change in heat furnished by the boiler, Btu/hr
ΔI = enthalpy difference in the heater between entering steam and drains, Btu/lb
Δi = enthalpy rise of the feedwater in the heater, Btu/lb
Δi_c = enthalpy drop of drains in the heater, Btu/lb
ϵ' = entering feedwater enthalpy increase, Btu/lb
ϵ'' = leaving drains enthalpy increase, Btu/lb
δ = entering steam enthalpy decrease, Btu/lb
W = feedwater flow, lb/hr
ω = leaving drains flow, lb/hr
W_e = extraction steam flow, lb/hr
f = (feedwater extracted)/(overall feedwater flow), lb/lb
q = main variation, Btu/hr
q_0 = heat introduced into feedwater between two consecutive heaters, Btu/hr
q_p = heat introduced by a pump, Btu/hr

DEFINITIONS

"Heater upstream of another heater"—means heater preceding in the direction of feedwater flow.
"Inlet terminal difference"—the temperature difference between the leaving drains and entering feedwater.
"Outlet terminal difference"—the temperature difference between saturated steam at heater and outlet feedwater.

the elimination of one or more feedwater heaters. In either event, simplified heat balances or other shortcut methods may be used, (1, 3–5).

Optimization of the heater terminal differences, the use of condensate drain pumps, and the location of the boiler feed pump require greater accuracy in calculation. Either detailed heat balances must be used, or the optimization method, to be presently described.

The theory underlying the proposed method is that any modification of a cycle may be simulated by fictitious additions and subtractions of heat in the basic cycle, since these have the same effects on turbine capacity and heat rate. This is similar to the perturbation techniques employed in the solution of many of the complex problems in the physical sciences. These fictitious additions and subtractions of heat in the basic cycle are to be identified as "main variations." A linear relationship is assumed to exist between the main variations and the thermodynamic effects in the cycle—that is, changes in turbine capacity and heat rate. It is further assumed that the thermodynamic effects of one or more modifications are equal to the algebraic sum of the thermodynamic effects due to each of the corresponding main variations.

To recapitulate, any modifications to the cycle may be expressed by the corresponding main variations, and the overall thermodynamic effects, M, of the modification may be expressed as:

$$M = (a)V_1 + (b)V_2 + \ldots \qquad (1)$$

where a, b—are the "main variations" corresponding to the modification, measured by taking as a unit the "main unit variation," and V_1, V_2—are the corresponding thermodynamic effects of the "main unit variation." This is a fictitious addition of heat of a fixed value, which may be selected arbitrarily, usually between 1 and 2 per cent of Q^b.

Determining Basic Cycle Heat Balance

The procedure for applying the foregoing theory consists first in the determination of the complete full-load heat balance of the basic cycle.

The main unit variation is then applied in the condenser, in each of the feedwater heaters, and in the boiler, and the corresponding thermodynamic effects are calculated by heat balances. The introduction of this extra heat in the condenser, for which the same loading and cooling water flow is maintained, results in a loss of vacuum with a consequent increase in the enthalpy of the steam to the condenser. A loss of power, ΔP ensues. As the heat supplied by the boiler is unchanged, the heat rate is adversely affected.

In the several feedwater heaters the introduction of the main unit variation causes a reduction in the bled steam with the probability of greater power development and reduction in heat rate.

The main unit variation introduced after the last high pressure heater will decrease that needed in the boiler and reduce the heat rate, however the bled steam flows remain the same and there is no change in power.

The changes are related to the basic cycle values as:

$$\Delta r/r_b = \Delta Q/Q_b - \Delta P/P_b \qquad (2)$$

Calculations of the thermodynamic effects of the modifications are facilitated by grouping the effects of the main unit variations as shown in Table I.

The steam saturation temperature in the several feedwater heaters are used as loci forming the abscissa of a graph in which the quantities listed in Table I are plotted. Representative graphs are shown in Fig. 1, 2, p. 38, and 3, p. 41.

The thermodynamic effects of a main unit variation in a 60 mw non-reheat cycle are shown in Fig. 1 If Fig. 1 were being used in a study to determine the number of feedwater heaters, approximate values of ΔP, ΔQ and Δr could be obtained by reading the respective ordinates at the saturation temperatures intermediate to those shown. However, it is important to note that to maintain the accuracy of the method, the addition of other heaters would require a new Table I and a complete re-calculation of the values in it.

Larger and more complex cycles have been represented in Fig. 2 and Fig. 3, to show the effects of reheating and higher throttle conditions. The trend of the curves in Figs. 1, 2 and 3 may be explained as follows:

(1) The ΔP and Δr curves show improvement as the saturation temperatures rise. This follows from the

TABLE I—THERMODYNAMIC EFFECTS DUE TO A MAIN UNIT VARIATION OF_____BTU/HR

Heat Addition in	Cdr.	1st Htr.	2nd Htr.		nth Htr.	Boiler
ΔP, kw						
ΔQ, Btu/hr						
Δr, Btu/kwhr						

Second Law of Thermodynamics and from the fact that as less steam is bled at the high pressure end of the turbine more work can be done.

(2) The ΔP curve flattens, or even slopes downward, in the last portion toward the boiler. This is due to the fact that only a portion of the heat introduced in the last heater is recovered as an increase in turbine capacity. The balance raises the final feedwater temperature, thereby reducing the heat supplied by the boiler.

(3) If the exhaust end of the machine is small, heat added in the L.P. heater could conceivably result in negative values for ΔP and positive changes in Δr. This might occur if the bleed pressure was very low, so that the small power increment produced by the extra steam flow was offset by the increase in the leaving losses.

(4) Where reheaters are used, the ΔQ is positive to the extent that increased steam flow through the reheaters offsets the rise in the final feedwater temperature.

(5) The step down occurring in the ΔP and Δr curves in correspondence to the cold reheat bleed, is due to the fact that steam extracted after reheating is highly superheated and, consequently, again by the Second Law of Thermodynamics, its utilization for feedwater heating involves a loss. This is the reason why the bleed after the reheating is placed normally quite far from it. Consequently the cold reheat bleed generally furnishes the feedwater with a larger quantity of heat than the other bleed points.

The economic value corresponding to a main unit variation can be determined from the graphs described above when the criteria and values of fuel cost, plant capacity factor, cost of money, and cost of installation are established. In Fig. 4 this value is plotted against the heater saturation temperatures for the cycle shown in Fig. 2. Curves A and B are based on equal plant capacity factors and fuel costs, but B exceeds A in cost of construction. Curve C represents variations in these items. Any number of curves could have been plotted in Fig. 4, depending upon the combinations of the variables involved.

The general rules to determine the main variations corresponding to a modification are as follows:

(*a*) First determine the heaters directly affected by the modification, (*b*) Perform a heat balance around each of these heaters, resulting in a change in bleed flow, (*c*) Then obtain the equation of the main variation in correspondence of each heater by the product of the change in bleed flow for the enthalpy difference between entering

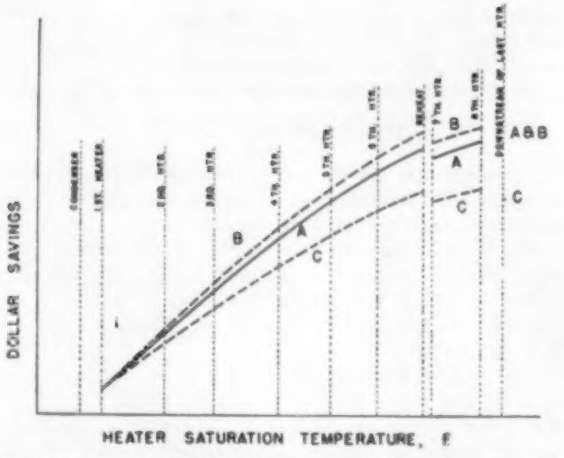

Fig. 4—Economical value of the thermodynamic effects of cycle shown in Fig. 2 appear above

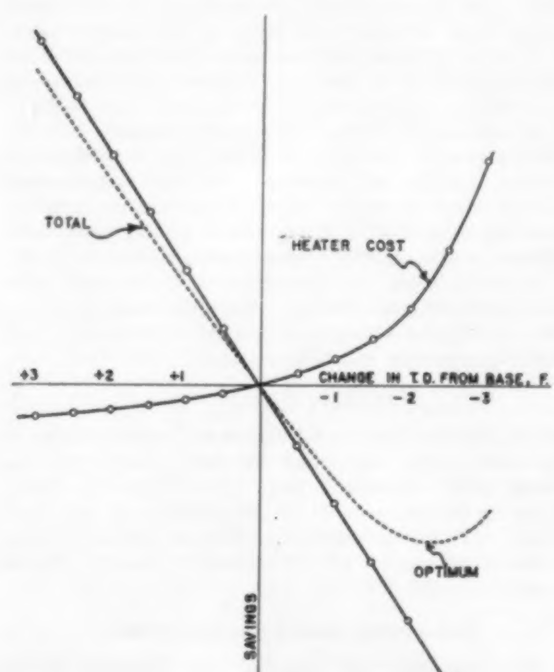

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Fig. 5—Optimization of outlet terminal difference for one of the heaters shown in Fig. 2

TABLE II, below, III right

Modification		Main variations of heater a	of heater b	of heater other than a, b
A) Change in inlet T.D (modified HTR)	exact	$q_a = -q_b$	$q_b = \frac{-\epsilon'' W_b}{1-\frac{\epsilon''}{\Delta I_b}}$	
	approx.		$q_b = -\epsilon'' W_b$	
B) Change in outlet T.D; C) Alteration in dia. of ext. str. piping (modified HTR)	exact	$q_a = -q_b$	$q_b = \frac{\epsilon' W - \epsilon'' W_b}{1-\frac{\epsilon''}{\Delta I_b}}$	
	approx.		$q_b = \epsilon' W - \epsilon'' W_b$	
D) Addition of heat recovering unit in the F.W. system	exact	$q_a = -(q_b - q_u)$	$q_b = \frac{q_u - \epsilon'' W_b}{1-\frac{\epsilon''}{\Delta I_b}}$	
	approx.		$q_b = q_u - \epsilon'' W_b$	
E) Addition of B.F.P. in F.W. cycle	exact	$q_a = -(q_b - q_p)$	$q_b = \frac{q_p - \epsilon'' W_b - \epsilon_b' W}{1-\frac{\epsilon''}{\Delta I_b}}$	of heaters where pressure is changed: $q_n = W(\epsilon_n' - \epsilon_{n+1}')$
	approx.		$q_b = q_p - \epsilon'' W_b - \epsilon_b' W$	

Modification		of heater a	of heater b	other
F) Addition of heater drain pump in F.W. cycle	exact	[illegible]	[illegible]	of upstream heater: [illegible]
	approx.	[illegible]	[illegible]	$q_n = W_b(\Delta i_n - \Delta i_{cn})$
G) Extraction steam separate desuperheating	exact	$q_a = -\frac{W_{sa}\,\delta}{1-\frac{\delta}{\Delta I_a}}$		of desuperheater location: $q_n = -\frac{W_{sn}\,\delta}{1-\frac{\delta}{\Delta I_n}}$
H) F.W. extraction	exact	$q_a = \frac{-W_{sa}\,\delta}{1-\frac{\delta}{\Delta I_a}}$	$q_b = \epsilon' W \Delta i_b$	at point where ext. heated water is readmitted: $q_n = -(q_b + q_a)$
I) Replacement of a surface heater by a contact heater	exact	[illegible]	$q_b = \frac{\epsilon' W - \epsilon'' W_b}{1-\frac{\epsilon''}{\Delta I_b}}$	of upstream heaters: $q_n = W_b(\Delta i_n - \Delta i_{cn})$
	approx.	[illegible]	$q_b = \epsilon' W - \epsilon'' W_b$	

steam and drains in the basic cycle, ΔI.

For a series of changes in the feedwater circuits covering the cases normally of interest, main variations have been evaluated according to the preceding rules and the resulting equations are given in Table II and Table III. The tables contain both exact and approximate equations. In general, the thermodynamic and economic inaccuracies are of the same order or magnitude, so the approximate equations are normally adequate. As an example, Modification A in Table II involves elimination of the second term of the denominator in the exact equation. For the changes anticipated the term $\epsilon''/\Delta I$ will be less than 2 per cent, and the approximate equation is reasonable within the cost range of the equipment changes which it will govern.

The equations of Tables II and III may be commented on as follows:

A. Change of a Heater Inlet Terminal Difference

Reducing the subcooling surface of a heater causes an increase in drain temperature and enthalpy, and consequently an increase in bleed steam. The main variation for this heater is then negative, i.e., a removal of heat.

The only other heater directly affected by the modification is the upstream one, into which the drains enter at a higher enthalpy. As a consequence, less bleed steam is required. Main variation of the upstream heater has the same value but opposite sign to that of the modified heater.

If the lowest pressure heater is modified, the change in the heat furnished by drains to it will involve a change, of equal amount but opposite sign, in the heat discharged in the condenser.

Editor's Note: Instead of varying the basic load and heat rate, the heater surfaces could be varied, which would result in a change in cost directly, based on the modifications, as the ratio of thermodynamic change is approximately proportional to the surface change. This approach is developed by John H. Cruise in an Appendix appearing on p. 44 at the close of this article.

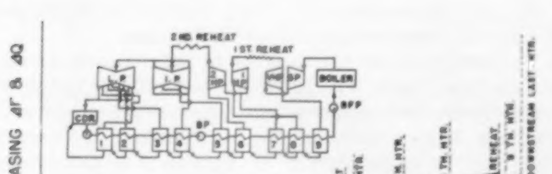


Fig. 3—Thermodynamic effects of a main unit variation of 50 million btu/hr on a 350 mw cycle, throttle conditions 5000 psig, 1200 F, reheat to 1050 F, second reheat to 1050 F.

B. Change of a Heater Outlet Terminal Difference

Increasing the condensing and/or desuperheating area of a heater causes an increase in bleed steam and a rise in the outlet feed temperature. Again, the main variation for the other heater directly affected by the modification, i.e., the downstream heater, is of the same amount, but with opposite sign.

If the highest pressure heater is modified, the change in F.W. temperature causes a main variation for the boiler.

C. Change in Extraction Piping Diameter

Variations in piping diameter cause changes in the pressure drop between the extraction point and the heater, reflected in the pressure and saturation temperature in the heater. As the terminal temperature difference at the heater outlet remains constant, there is a change in the feed outlet temperature. Changes in extraction piping diameter give, therefore, a main variation as in case B.

D. Heat Introduced into the Feedwater from an Outside Source

Here the modification affects the heater downstream of the point of application in the same manner as case B, and consequently the main variation is the same. The main variation for the upstream heater is equal to the difference between the heat recovered and the main variation for the downstream heater.

E. Addition of Booster Pumps in the Feedwater Circuit

An additional pump causes a temperature rise in the water, with effects similar to case D, and a rise in pressure reflected in enthalpy rises downstream.

F. Addition of a Drain Pump in the Feedwater Circuit

Introducing a drain pump as shown in case F, Table III, causes:

(*a*) A rise in temperature of the heater drains due to the elimination of the subcooling zone, and

(*b*) A slight change of enthalpy to the downstream heater due to mixing, and

(*c*) At all heaters between the condenser and the drain pump there will be a substantial reduction in feedwater flow and an equal reduction in drain flow.

G. Separate Desuperheating of Bleed Steam

Sometimes there is justification for a separate desuperheating of the bleed steam at a high point in the feedwater circuit as shown in Table III. If this desuperheater is downstream of the last heater, there is only an enthalpy rise of the final feedwater. If the desuperheating is done between two feedwater heaters the criteria of case D will apply. The heat balance around the heater receiving the desuperheated steam shows an increase in bleed flow, and consequently the main variation for this heater is negative.

H. Feedwater Extraction

Partial feedwater flow may be combined with separate desuperheating (9) as shown in Table III. The general relations developed for case G will apply for the heater receiving the desuperheated steam and for the reentry point. The main variation for each heater between the water extraction point and reentry point is proportional to the change in feedwater flow.

I. Replacement of a Surface Heater by a Contact Heater

Should a surface heater be substituted by a contact heater, the heaters affected by the modification are the same as in case F, but the heat balances around the heaters are slightly different.

Optimizing Terminal Temperature Differences

Once the first part of the calculation has been performed, Table I has been completed, and graphs similar to those of Fig. 1, 2, 3 and 4 have been drawn, the evaluation of economic gain due to any modification is very quick and easy. As an example, optimization of outlet terminal temperature differences of the heaters may be performed as follows:

(1) Using the approximate formulae in Tables II and III, the main variations are seen to be proportional to the changes in terminal temperature differences. To evaluate the main variations, the first part of Table IV is prepared on the basis of a change of 1 deg F in terminal differences; other changes are obtainable by proportion.

(2) The second part of Table IV is then prepared, using the result of the preliminary calculation reported in Table I.

TABLE IV—BASIC DATA FOR EVALUATION OF GAINS FROM CYCLE MODIFICATIONS

Heater No.		1	2	3		n
W	lb/hr					
ω_b	lb/hr					
ϵ'	Btu/lb					
ϵ''	Btu/lb					
q^b	Btu/hr					
ΔP	kw					
Δr	Btu/kwhr					
ΔQ	Btu/hr					
Value	$					

(3) The value of the thermodynamic effect of the modification is then algebraically added to the cost of heaters.

From the basic design the terminal temperature differences and heater surfaces are known. The cost of changes in the terminal temperature differences may be estimated, or may be obtained from the heater manufacturer. This determination is facilitated by the use of Table V, relating the heater area changes from the basic design due to small changes in the terminal temperature differences.

TABLE V—HEATER AREA CHANGES FROM THE BASIC DESIGN

Heater No.	Heater Area Increments	
	T.T.D. greater than basic	T.T.D. below basic
1 2 3 n	surface areas decreasing	surface areas increasing

This is then followed by Table VI, in which the heater cost and thermodynamic effects values are combined for several terminal temperature differences.

In order to limit the number of calculations, several values from Table VI can be plotted and the optimum value determined graphically. This has been indicated, for one heater only, in Fig. 5. A final tabulation can then be made, listing the optimum terminal temperature difference for each heater and the overall saving referred to the basic cycle.

Discussion

It is readily apparent that with the large array of variables the number of calculations can become excessive. Experience in the application of the method and a knowledge of the performance of similar cycles will reduce the number of alternatives and hence the time for computation. Once the optimum values are determined for each of the modifications, the best feedwater heater cycle for the plant can be found modifying the basic cycle by each of the changes which will improve it.

TABLE VI—COMPILATION OF VARIOUS HEATER AREA COSTS AND THERMODYNAMIC ADVANTAGES

Heater	T.T.D. Above Basic					T.T.D. Below Basic				
1st Heater cost Thermo. value										
Total $										
2nd Heater cost Thermo. value										
Total $										
nth Heater cost Thermo. value										
Total $										

The designer then prepares a final heat balance of the optimized cycle to determine the turbine and station heat rates and the net power output. This also serves to check the assumption upon which the changes were made.

A qualitative indication of the best places in which the initiate changes can be found from a study of Fig. 4. As examples, the choice of the final feedwater temperature and the locations of the heaters can be weighed. As a first approximation, the gain to be realized from an introduction of heat upstream of the economizer is an index of the maximum regeneration justifiable. This is the criterion for the location of the highest pressure extraction.

The approximate and exact equations given in Tables II and III have been compared in Table VII for a modern large steam turbine cycle. It is apparent that great accuracy can be obtained with the approximate equations.

TABLE VII—COMPARISON OF VALUES FROM DIFFERENT TECHNIQUES FOR A TYPICAL LARGE TURBINE CYCLE

Values Obtained By:	P (kw)	r (Btu/kwhr)
Heat balance	+2705	−2.6
Approx. equation	+2696	−1.9
Exact equation	+2709	−2.2

Conclusions

As it was the purpose of this paper to present in concise form the Edisonvolta method, detailed calculations have been omitted.[2]

Superficially, the Edisonvolta approach appears complicated. However, an extremely logical and systematic method has been presented for analyzing the effects of even the small changes in the regenerative steam turine cycle. Italian experience has verified by comparison with traditional heat balance procedure the usefulness and accuracy of the method, which has been used to optimize, among others, the cycle of the new Edisonvolta installation at La Spezia, Italy. The first unit of this is a 320 mw, in which the steam conditions are 2400 psig, 1050 F, with reheat at 1000 F, and an absolute backpressure of 1.5 in. Hg. It is to be hoped that the proposed method will be taken up by the design engineers in this country.

The authors wish to express their thanks to Dr. Ing. G. Amedei and Mr. G. Fossati for their valuable cooperation. Thanks are also due to Mr. A. Gnesutta and Mr. J. B. Prather.

[2] For a more detailed study see reference (12).

BIBLIOGRAPHY

(1) Salisbury, J. K., "Steam Turbines and Their Cycles," John Wiley & Sons, New York, 1950.

(2) Salisbury, J. K., "Analysis of the Steam-Turbine Reheat Cycle," *Tr. ASME*, **80**, 1958, 1629–1642.

(3) Bollier, H., "The Gain Obtainable from Regenerative Feed Heating," *Echer-Wyss News*, 1951.

(4) Keller, A., "The Evaluation of Steam-Power-Plant Losses by Means of the Entropy-Balance Diagram," *Tr. ASME*, **72**, 1950, 949–953.

(5) Meyer, C. A., Silvestri, G. J., and Martin, J. A., "Availability Balance of Steam Power Plants," *Tr. ASME*, **81**, 1959, 35–42.

(6) Bartels, J., "Thermodynamics of Supercritical-Pressure Steam Power Plants," *Tr. ASME*, **77**, 1955, 705–714.

(7) Holmes, A. C., and Hollitch, R. S., "A Steam Properties Program for Medium and Large Computers," ASME Paper 57-A-278.

(8) Paquet, A., "La Condensation et Le Poste D'Eau D'Une Centrale Electroque Moderne," *Bulletin de L'AIM*, Liege, Nov.-Dec. 1958.

(9) Ricard, J., "Amelioration Du Rendement Du Cycle A Surchauffe Et a Resurchauffe Par Des Soutirages D'Eau Aux Rechaffeurs," *Chaleur et Industrie*, **39**, Feb. 1958, 27–49.

(10) Church, E. F., Jr., "Steam Turbines," McGraw-Hill, New York, 1950.

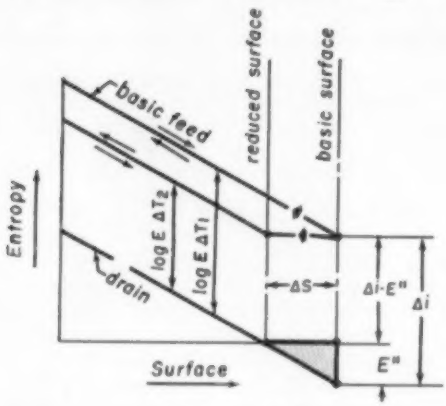
(11) Stephani, R. M., "How to Choose Your Feedwater Heaters," *Power*, **101**, No. 6, June 1957, 82–84.

(12) Chiantore, G., Borgese, D., and Baldo, F., "Un Metodo Rapido Per La Determinazione Del Ciclo Rigenerativo Piu Economico Di Un Impianto Termelettrico," *La Termotecnica*, XIV, No. 1, Jan. 1960, 3–24.

Appendix—Sample Study of Surface Change Effects Upon Cycle Efficiency

By JOHN CRUISE

DRAIN THERMAL EFFICIENCY $= \frac{\Delta i - E''}{\Delta i} = 1 - \frac{E''}{\Delta i}$



SYMBOLS

R	=	Overall heat transfer rate
W_f	=	Weight of feed, lb/hr = 1.0
w_d	=	Weight of drain, lb/hr = 1.0
c/p_m	=	Mean specific heat
S	=	Surface, sq. ft
$\text{Log}_E\ \Delta T$	=	Log_E mean temperature difference (basic feed − drain)

Basic heat balance $= W_f - c/p_m \Delta T_f = w_d c/p_m \Delta T_d = RS(\text{Log}_E \Delta T)$

NOTE: Within the limit of change, the transfer rate, pressure drop, and $\text{Log}_E \Delta T$ are considered constant. The transfer rate and pressure drop are assumed compensated for in a final heater design by a change in diameter or length or both. The $\text{Log}_E \Delta T$ is of small degree.

Heat balance based on the drain system

$$w_d c/p_m \Delta T_{d_1} = RS(\text{Log}_E\ \Delta T) = \text{Basic cycle}$$

$$w_d c/p_m \Delta T_{d_2} = R(S \pm \Delta S)\ \text{Log}_E\ \Delta T$$

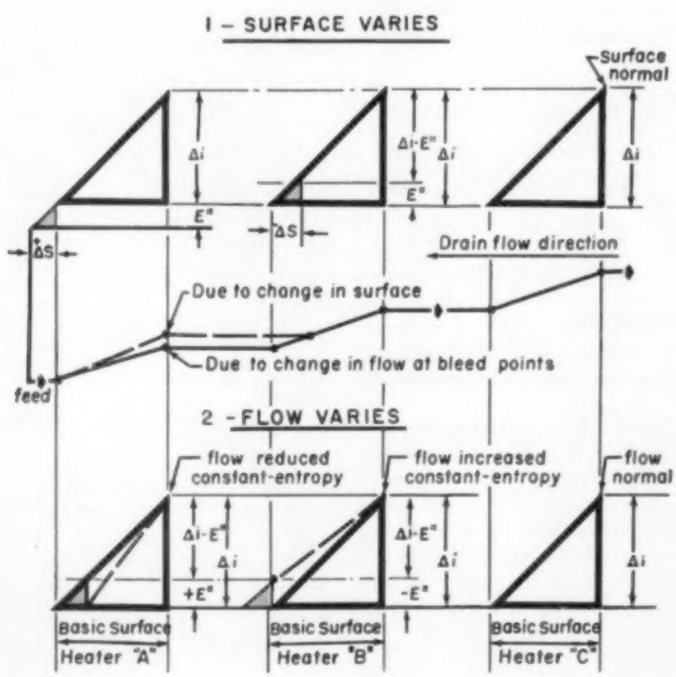
$$\frac{w_d c/p_m \Delta T_{d_1}}{w_d c/p_m \Delta T_{d_2}} = \frac{RS\ \text{Log}_E\ \Delta T_1}{R(S \pm \Delta S)\ \text{Log}_E\ \Delta T_2}$$

$$\frac{c/p_m \Delta T_{d_1}}{c/p_m \Delta T_{d_2}} \approx \frac{S}{(S \pm \Delta S)} \approx \frac{\Delta H_1}{\Delta H_2}$$

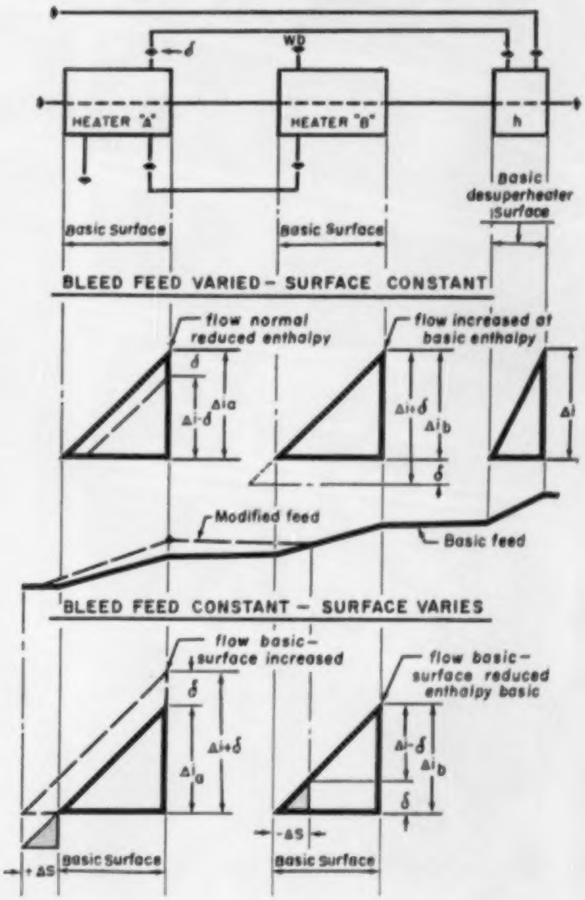
It is thus established that a change in surface is approximately proportional to a change in enthalpy.

PREMISE ABOVE PLOTTED OUT

Scheme showing relationship of two concepts to achieve basic cycle conditions—(1) Change in surface, (2) change in bleed flow.



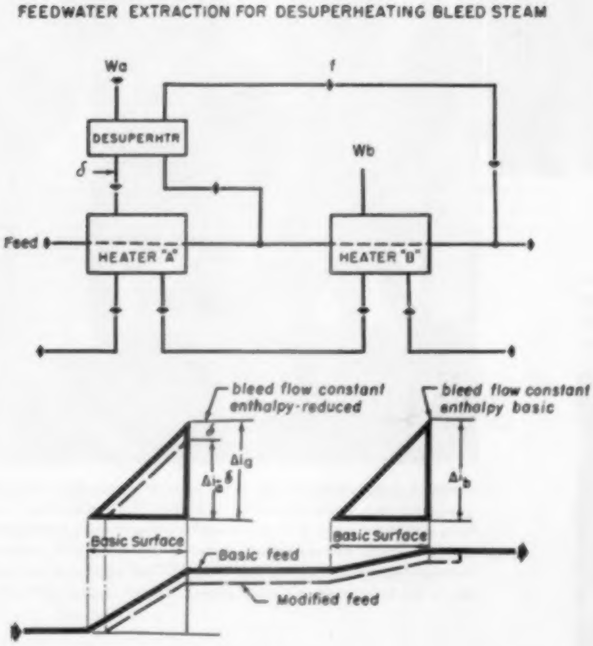
BLEED STEAM DESUPERHEATED BY EXTRACTED FEED IN A SEPARATE DESUPERHEATER



Authors' Case G, Table III, P. 41

Plot Comparison:
Surface Vs Flow Change

FEEDWATER EXTRACTION FOR DESUPERHEATING BLEED STEAM



Authors' Case H, Table III, P. 41

Δi_a = Enthalpy difference in the heater between entering steam and leaving drains
Q = Main variation, Btu/hr
Wv_a = Extraction steam flow, lb/hr
δ = Decrease in entering steam enthalpy
r = Fraction of feedwater extracted from overall flow

Thermal efficiency Heater "A" =

$$\frac{\Delta i_a - \delta}{\Delta i_a} = 1 - \frac{\delta}{\Delta i_a}$$

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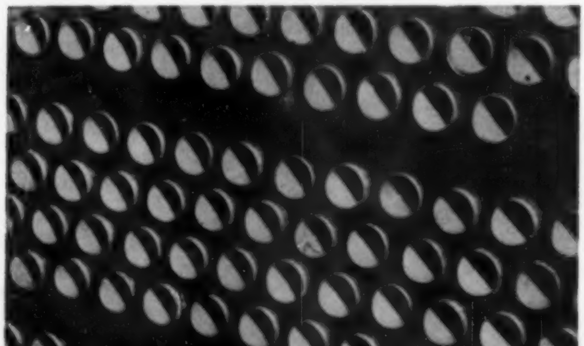

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18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

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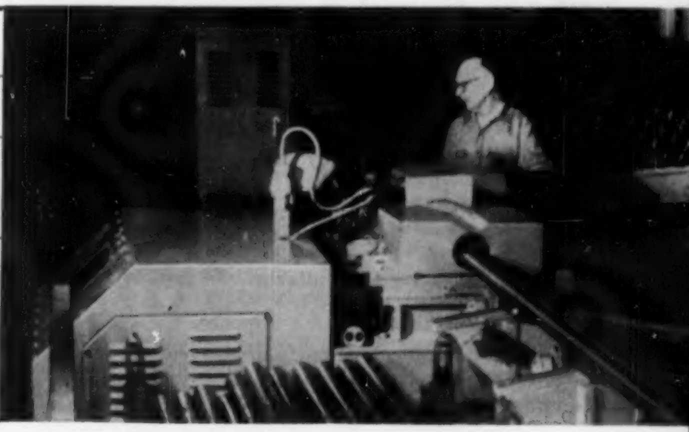

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By IGOR J. KARASSIK*

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part XXII

QUESTION

Our power plant is isolated from any other electric system. Recently, our load has grown to the point that we have practically no reserve over the peak demand and a new unit will be added shortly. In the meantime, occasions arise when the load exceeds the installed capability and causes a reduction in frequency for as long as one hour or one hour and a half. Obviously, this reduction in frequency has the effect of slowing down all electric-driven auxiliaries. I am primarily concerned with the boiler feed pumps as I suspect that this reduction in speed might render them incapable of maintaining the required rate of feeding. Can you indicate a method whereby the effect of frequency variation on the capability of the boiler feed pumps may be predicted, so that we can find out whether we are in serious trouble, or rather danger from that quarter?

ANSWER

Because a centrifugal pump is a velocity machine, a change in speed will affect the head-capacity curve of the pump. Since all velocities in the pump impeller and in the casing (*for similar points on the characteristic curve*) will vary in direct proportion to the peripheral velocity, it becomes very easy to calculate the effect on the head-capacity curve. The pump capacity, which is a direct function of the velocities, will vary directly as the operating speed. The total head, which is a function of the square of the peripheral speed, will vary as the square of the operating speed. Finally, since the power consumption varies as the product of the head and the capacity, the power will vary as the cube of the operating speed.

We can, therefore, prepare a tabulation of factors by which we can multiply the capacity and head points of a pump curve so as to predict the pump characteristics at any frequency other than the rated frequency. If the latter is 60 cycles, these factors will follow Table I.

You use these factors to prepare a family of head-capacity curves for your boiler feed pumps for any frequency between 60 and 55. (I earnestly hope that you are not faced with anything as drastic as such a reduction.) A typical example is given on Fig. 1, in which a

* Consulting Engineer and Manager of Planning, Harrison Div.

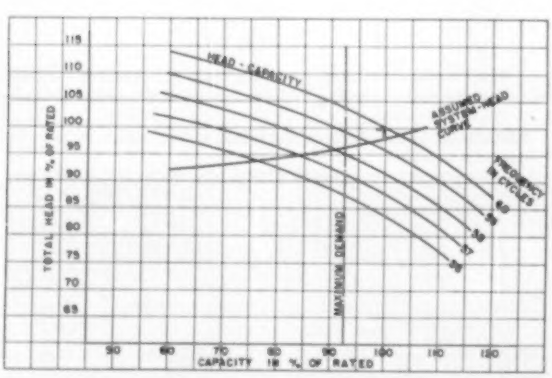


Fig. 1—Effect of frequency variation on relation between H-Q and system-head curves

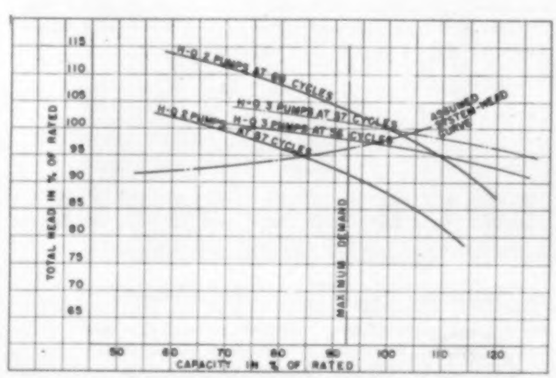


Fig. 2—Operation with 2 and 3 pumps in parallel at varying frequencies

TABLE I

Frequency	Capacity Multiplier	Head Multiplier
60	1.00	1.00
59	0.983	0.967
58	0.967	0.935
57	0.95	0.903
56	0.933	0.871
55	0.917	0.84

typical performance curve of a boiler feed pump is expressed in terms of percentages of its rated conditions at 100 per cent speed (or 60 cycles) as well as at lower frequencies. Thus, for instance, with the frequency reduced to 56 cycles, the rated point of 100 per cent capacity and 100 per cent head will have been reduced to 93.3 per cent capacity and 87.1 per cent head.

Whether frequency reduction will impair the ability of your boiler feed pumps to deliver sufficient feedwater to the boiler will depend in part upon the extent of frequency reduction and in part upon the margin that has been included over and above the system demand in selecting the rated conditions of the pumps.[1] To illustrate this point, I have assumed in constructing Fig. 1 that 8 per cent has been added to the maximum capacity requirements and that the pump head has been selected arbitrarily at 2 per cent above the system-head at the rated capacity so established. Thus, at the normal maximum demand, the pump capacity must be 92.5 per cent of rated and the head 96.5 per cent of rated.

If this be the case, and assuming that the pump is not worn, the frequency could drop to 58.3 cycles without preventing the pump from delivering the full maximum demand flow to the boiler. If, however, the frequency were to drop to 56 cycles, the head-capacity curve would intersect the system-head curve at 76 per cent of rated capacity of 82.2 per cent of the maximum demand.

Of course, if the pump is worn appreciably and internal leakage has reduced its effective capacity appreciably below its rating, the effect of frequency reduction will be more severe in restricting the ability of the pump to deliver sufficient flow to the boiler. This consideration leads to the recommendation that if your pumps have not been reconditioned for a long time, renewing internal clearances may well be indicated at this junction.

Another suggestion may be in order if your installation includes spare equipment. Assuming, for instance, that your unit is served by three pumps of which two are running for full load and one is a spare, running this spare pump whenever you are expecting frequency reduction may get you over the hump until your new unit is available. Fig. 2 illustrates the effect of running three such pumps under reduced frequency conditions. You will note that even were the frequency to drop to 55.5 cycles, the three pumps will still deliver the maximum demand. Of course, it may be wise to start the spare pump in advance of the anticipated frequency reduction, lest the starting current impose further difficulties on your plant once it is loaded beyond its normal capacity.

[1] For a more complete treatment of this problem, see "Boiler Feed Pump Response to Electrical Fluctuations." *Electric Light and Power*, Aug. 15, 1959. Also, "Steam Plant Operation under Emergency Conditions—Effect of Frequency and Voltage Fluctuations on Centrifugal Pump Auxiliaries," presented at PCEA Meeting, March 27–28, 1958, Worthington Reprint RP-1046.

Question

Is it common practice to install a relief valve in the suction piping of a boiler feed pump?

Some of our engineers are in favor of such a relief valve as protection against the building up of discharge pressure in the suction line when the suction line valve is closed. Others, including myself, feel that our present system incorporates all of the normal protective features required and that the addition of the relief valve is not justified. Building up of discharge pressure in the suction line can only occur under certain operating conditions and then only when valves have been operated incorrectly.

The enclosed sketch, Fig. 3, shows the system as now installed. Normally, one pump is on standby service with both suction and discharge valves open. Under these conditions, the discharge pressure cannot build up in the suction line. If the suction valve is closed, discharge pressure can build up in the pump and suction line only when one of the following conditions exists:

1. *Hand valve in recirculation line closed.*
2. *Recirculation control valve closed.*
3. *Leakage past check valve more than 130 gpm.*

The hand valve is a "locked open" valve which, under normal operation, should never be closed. The recirculation control valve is open with no flow in the suction line. This valve also fails "safe" in the open position, should there be loss of control air. This leaves only excessive leakage through the check valve as a cause of excess pressure in the suction line. Since the pump operator should never close the suction valve without first closing the discharge valve, this condition is also eliminated.

To prevent reverse rotation in the pump due to excessive leakage past the check valve, it is our practice to close the discharge valve immediately after stopping a pump. The valve is then opened and a careful check made to see that the pump is not rotating in reverse.

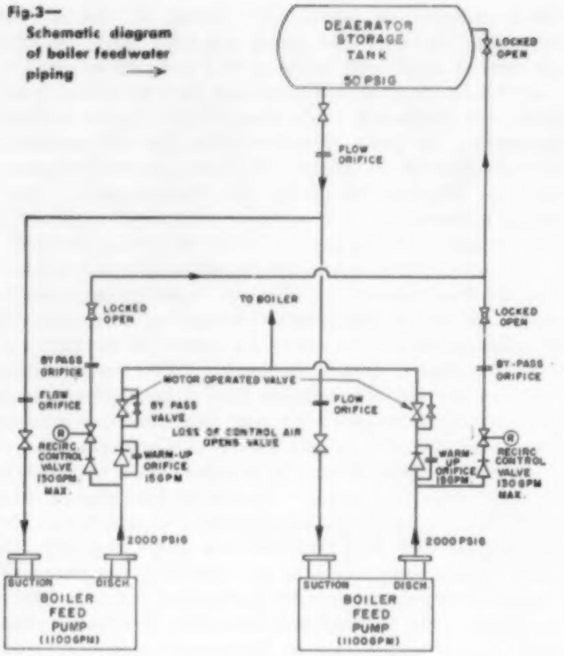
Your comments on this problem would be most helpful and greatly appreciated.

Answer

The practice is very far from being common, though I have seen relief valves incorporated in a few installations. It is my opinion, very frankly, that there is no justification for its use in the case you have described. As you say, it would require an unusual accumulation of circumstances and of operational errors to cause any difficulty in the absence of a relief valve. Such an accumulation would come under the heading of triple or quadruple contingency and power plant designers cannot afford to protect a steam power plant against this. After all, there are many more areas in a plant where protection against multiple contingencies would be equally justifiable and where no such protection is employed.

In general, my reaction to a problem such as this is to start with the proposition "It is always a risk to operate a steam power plant." If we wanted to eliminate *all* risks, we couldn't afford to build one. Therefore, our real problem is to properly classify all the individual risks we shall encounter and establish which of these risks we can afford to eliminate, which risks we can only

Fig. 3—
Schematic diagram of boiler feedwater piping →



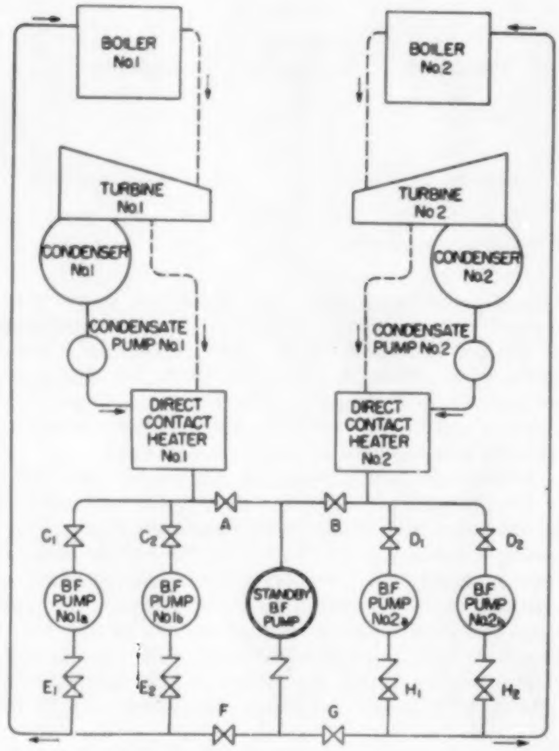


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Fig. 4—Standby B. F. pump valving

minimize and which ones we must endure. My opinion is that in the case you have described, the risk of encountering a combination of circumstances which would cause difficulty if no relief valve were provided, falls into the group of risks we must endure.

The only arrangement where more serious consideration might be given to the use of a relief valve is that where a single spare pump is used for two adjoining units (see Fig. 2). Here, there are two suction valves, one in each of the lines from the two deaerators. Normally, one or the other suction valves are kept open, but there is a greater chance that both valves might be closed by error. Since the recirculation lines (not shown on the illustration) will also be provided with alternate connections to the deaerating heaters, so as to return the bypass flow to the proper unit, there is also a greater chance that both lines may be blocked closed. In this case, then, including a relief valve may be considered as sound protection. But even here I would feel that the valve is optional and not mandatory.

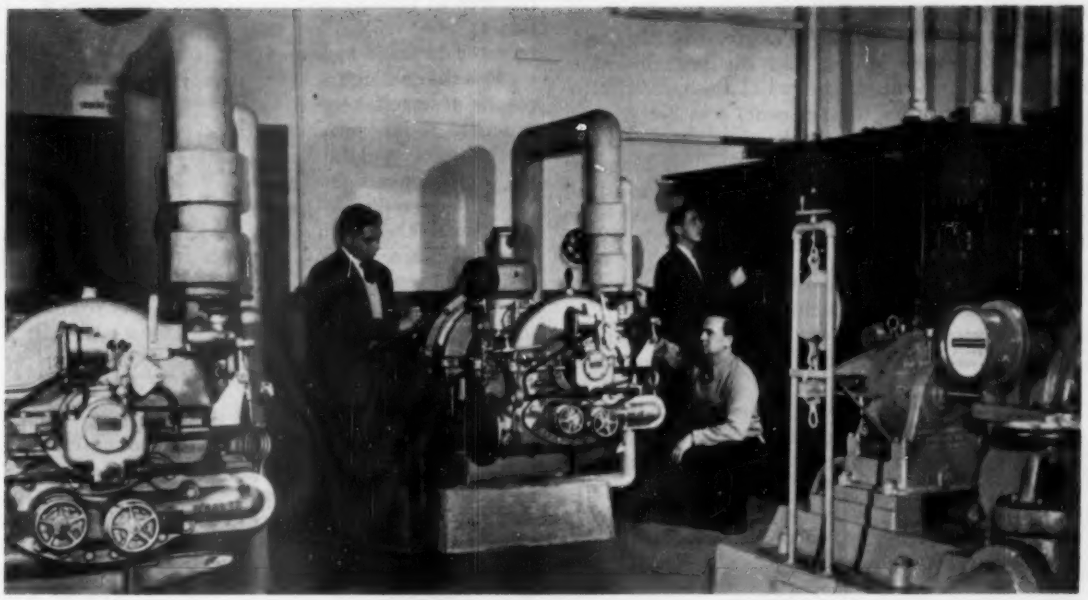
Reverse rotation caused by leaking or sticking check valves is a matter which has frequently caused me concern. I am therefore very much in agreement with your procedure to close the discharge valve on a pump that is taken off the line until the operators are sure that the check valve is operating properly. I actually prefer to see the valve closed first and *then* the driver tripped out, assuming that we are dealing with a scheduled operation and not an emergency. Even with a motorized valve it may take up to 30 sec. for complete closure. If the check valve is faulty and the discharge valve is *closed* after the pump is tripped out, by the time the flow is interrupted, the damage from reverse rotation may already have occurred. The discharge valve can be closed while the pump is running since the automatic bypass recirculation protects the pump against operation at shut-off.

Air Pollution Control Association Meeting

The 54th Annual Air Pollution Control Association Meeting will be held June 11–15 at the Hotel Commodore in New York City, Harry A. Belyea, Association President and Chief Air Pollution Control Officer of Metropolitan Toronto, Canada, announced recently. Approximately 500 of the nation's leading authorities of air pollution control are expect to attend the five-day meeting. The theme of this year's meeting is "Air Pollution Is Everybody's Business." A. J. Benline, Commissioner, New York City Department of Air Pollution Control, is this year's conference chairman.

Eighteen technical sessions have been planned, at which scientists, researchers, physicians, industrialists and officials of Federal, state and local governments will present some 80 papers on a wide variety of subjects. Included among the papers will be discussions on instrumentation, pollution standards, health, incineration, fuels, control equipment, meteorology, research and many others.

On display will be an exhibit featuring the latest instruments and most modern advances in the air pollution abatement equipment field.



Hiring Engineering Graduates—Why and How

An engineering college has two prime responsibilities fundamental to its nature and function. It must impart knowledge to the student and it must develop and store knowledge. Obviously the dedication of teaching talent to research under the latter function must detract from undergraduate education under the former. Acting on a number of indications that the quali y of engineering education was beginning to suffer from emphasis on research, COMBUSTION attempted to discover the importance of prestige schools—(those getting the largest research grants) in the recruiting of engineers. At the same time we attempted to uncover the personal characteristics most highly valued by employers of engineers. The results, covering the hiring of nearly 8000 engineering graduates annually, are both interesting and enlightening.

We at COMBUSTION have felt a growing concern about the quality of engineering education at the undergraduate level. Is it true, for example, that when a university is awarded a new grant for research it becomes almost axiomatic that skilled teaching talent is taken away from the classroom and devoted to the research project? If so, it follows to our way of reasoning, that the schools receiving the most research dollars would be experiencing the greatest difficulty in maintaining their standards of undergraduate education. The very universities who boasted the finest faculties would find their ranks decimated by immediate and pressing demands of research projects. Individuals concerned with admissions to graduate schools of engineering tend to corroborate these conclusions. We wondered therefore how much importance industry was now attaching to the quality or reputation of an engineering school in their current recruitment of engineers. Was matriculation at a prestige school a "must" or just icing on the cake? Were other factors more important to employers in selecting new engineering talent? Which were the most important?

Currently available answers we found conflicting and vague so we went directly to the source—the employer—for some answers. The employer—whether he is right or wrong in his approach to recruiting—is the man who must be satisfied.

Electric Utilities and Industrials Quizzed

The search started with the top 100 industrials from Fortune Magazine's listing and 40 electric utilities hand-picked to include the largest and smallest (investor-owned) and to represent all corners of the nation. Response from the utilities (62 per cent) was better than the industrials (50 per cent) and here we encounter the first of many, many surprises. We received unusable replies from a number of the country's largest industrial concerns stating that they were unable to participate because.

(1) Their annual recruitment was not large enough to offer any significant conclusions.
(2) There were no convenient or accessible records.
(3) There was no centralized recruiting program or records.
(4) One employer could not give us a breakdown by schools because of decentralized records but stated that geography was his prime recruiting factor.
(5) Two refused to participate believing we were asking them to rank schools according to academic excellence.

Usable replies covered the hiring of nearly 8000 engineers annually. This number represents about 25% of all engineering graduates for the year. The majority, of course, were reported from the industrial ranks. The breakdown:

	Bachelor Degree	Advanced Degree	Totals
UTILITIES	332	22	354
INDUSTRIALS	6105	1395	7500
TOTAL	6437	1417	7854

It was especially gratifying that most respondents identified themselves and all showed interest in securing a copy of the results.

The Questions

Combustion's questionnaire was designed to elicit this information:

(1) Number of engineers recruited annually:

(a) With the bachelor degree.
(b) With advanced degrees.

(2) The ten schools from which the respondent drew the majority of these engineers (in each category).

(3) Had the employer discovered any qualities of engineer recruits which were indicators of future success in his business?

(4) What were these qualities—what was their order of importance?

(5) Regardless of whether or not item (4) had been answered we asked that the following be ranked in order of importance as indicators of success:

(a) Quality of School.
(b) Standing in Class.
(c) Extra-curricular activity.

Prestige Engineering Schools Defined

In order to draw any rational conclusions it is necessary to define what we mean by "prestige" schools. Between 1940 and 1958, Federal expenditures for scientific research at colleges and universities grew from $15 million to $440 million annually (1).[1] World War II contributed in large measure to this startling growth and we find that a handful of key universities have done most of the research needed to develop the atomic bomb, practical radar, proximity fuse, jet propulsion, servomechanisms and the like. Fewer than 75 universities and colleges share most of the available research dollars. We further reduced this list to the 19 schools that are linked with the 28 university-associated Federal research centers. These 19 universities shared about $200 million in Federal research funds in 1958–1959.(1) Combustion selected the best known dozen universities from this list as an arbitrary "prestige" base for this study.

How Prestige Schools Rank in Recruiting

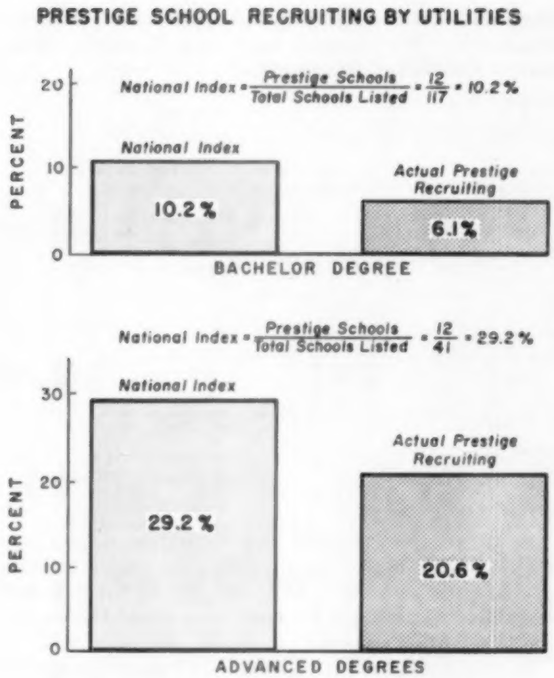
To establish a fair picture of the importance employers attach to the prestige rating of engineering colleges we used this procedure. We totaled the number of schools listed as recruiting sources in each group. The twelve selected prestige schools then represented some fixed percentage of this total and we called this fixed percentage the "national numerical index." So if 120 schools were mentioned by utilities the 12 prestige schools would numerically constitute 10 per cent—and the "national numerical index" for the group would be 10 per cent. Thus we would expect 10 engineers out of every 100 hired in this group to come from prestige school sources if this is a significant factor. The national numerical index for each of the four groups is shown below together with the actual percentage of recruiting from the prestige schools.

	Bachelor Degree		Advanced Degree	
	Nat'l Numerical Index (%)	Actual Sources (%)	Nat'l Numerical Index (%)	Actual Sources (%)
UTILITIES	10.2	6.1	29.2	20.6
INDUSTRIALS	10.2	19.4	16.4	34.8

These results shown graphically in Figs. 1 and 2 indicate clearly that utilities are recruiting below the "fair share" figure that the numerical index would indicate should be drawn from prestige schools. We can not conclude that a trend has been established here because of the small size of the sample as compared to the industrial sampling. Large industrials appear to be recruiting from our prestige schools at a rate nearly twice what the "fair share" numerical index indicates. Note that this holds true for bachelor degree recruits as well as for men with advanced degrees. Part of the discrepancy between categories may be accounted for by the fact that the utilities do not require physical scientists or mathematicians to the same degree that would be essential to a computer or aircraft manufacturer, for instance. There is agreement in that both types of employers look more often to the prestige schools when selecting engineers with advanced degrees. (The prestige schools should score more heavily in this area since all 12 offer graduate degrees whereas many of the others do not.)

At any rate, there is practically no evidence that our concern over research detracting from the quality of undergraduate engineering instruction is presently shared

[1] Numbers appearing in parentheses refer to similar numbered References appearing at the end of the article.



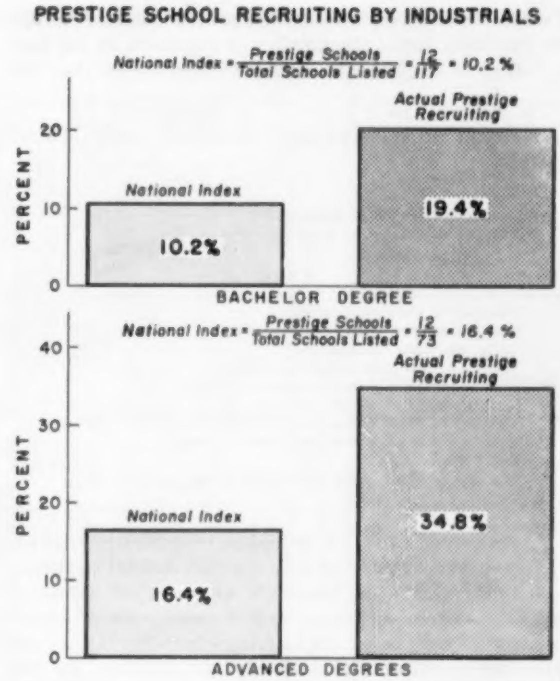
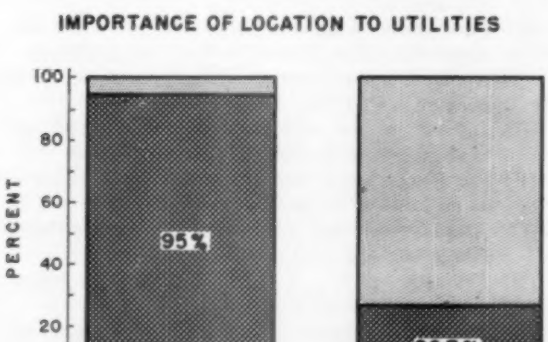


Fig. 1—(left) and Fig. 2 show the part played by prestige schools in engineering recruiting by utilities and and industrials

by employers. There is one significant factor that could change the entire perspective of the picture as we have presented it so far—and that is geography. Later it will be shown that location of a school is far and away the most important single factor in recruitment. In fact the favorable position of prestige schools, Figs. 1 & 2, would be almost completely destroyed if we were to conclude that employers hired on proximity rather than prestige. Obviously however, we had no way of knowing whether a recruit was selected from a given school because of its prestige or because of its location. We doubt even that many employment records could offer this information. This being the case, the prestige schools were given the benefit of the doubt in all tabulations.

Geography in Engineering Recruiting

In "Why Engineers Work" (2) Eugene Raudsepp says "Within the last few years, location has become one of the more influential factors in engineer job selection. At present, among material attractions, it runs a close second to salary." This interest among engineers in where they work, combined with the convenience accruing from local recruiting, probably accounts for the rather startling results shown in Figs. 3 and 4. These illustrations show the amazing degree to which recruiting is done on a geographical basis. In arriving at the breakdown shown here the "adjacent geographically" figures include in-state schools and schools in states bordering on the employer's home state. One instance is typical



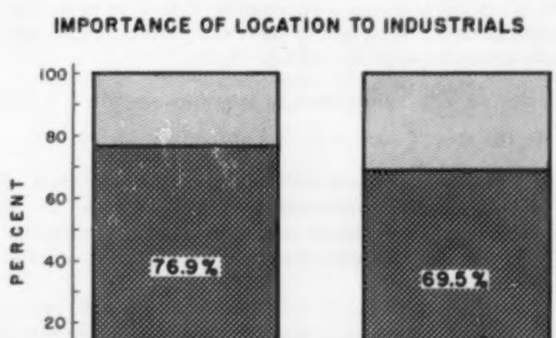


Fig. 3—(left) and Fig. 4 show how important a part is played by geography in recruiting engineers

of many reports but is somewhat more revealing in that this employer listed the number of engineers *on his staff* by college of origin. The reader will remember that our questionnaire had asked only for the sources of *annual* recruitment. The following tabulation shows the breakdown of this one engineering staff.

TABLE I—COLLEGE ORIGIN OF ONE INDUSTRIAL COMPANY'S TOTAL ENGINEERING STAFF

	In-State	Adjacent Geographically	From Prestige Schools
Number of Bachelor Degrees	436	61	95
Number of Advanced Degrees	263	5	44

	Bachelor Degrees No.	Bachelor Degrees %	Advanced Degrees No.	Advanced Degrees %
Number of Colleges Listed	10	100	10	100
In-State Source Colleges	7	70	6	60
Adjacent State Colleges	3	30	1	10
Total In-State and Adjacent Colleges	10	100	7	70
Number of Staff From In-State Colleges	436	87.7	263	95.2
Number of Staff From Adjacent State Colleges	61	12.3	5	1.8
Number of Staff From In-State and Adjacent Colleges	497	100	268	97.1
Number of Staff From Out-State Colleges	0	0	8	2.9
Total Staff	497	100	276	100
Number of Staff from Prestige Schools	95	19.1	44	15.9

In reviewing Table I it should be remembered that the picture covers total staff and not just annual recruiting which, for this firm, presently amounts to about 55 bachelor degree engineers and 5 men with advanced degrees. Facilities for engineering education within this state are excellent and probably accounts for the fact that local recruitment is higher than the national average in both bachelor and advanced degrees. Note that number of staff with advanced degrees from prestige schools (15.9 per cent) is far below the national average (34.8 per cent) but very close to the national numerical index (16.4 per cent). Reasons for this are two:

(*a*) Disagreement—Many of the staff have undoubtedly earned advanced degrees at in-state schools *after* employment.

(*b*) Agreement—Numerical index of local prestige schools is very close to the national index.

A further discrepancy exists between the number of bachelor degree staff from local schools (100 per cent) and the national average (76.9 per cent). This variation we attribute to the exceptionally high number of excellent engineering schools in this state. This apparently is one area that can meet all its needs and more. The number of bachelor degree staff from prestige schools (19.1 per cent) is very close to the national average (19.4 per cent) but is surprising in that it reverses the national trend being larger than the percentage of men with advanced degrees (15.9 per cent).

Indicators of Success

In the area of success we asked for three items:

(1) Has your experience indicated characteristics of engineering graduates that have proved to be indicators of future success in your organization?

(2) Will you please list these characteristics in order of importance?

(3) If you have not included quality of school, standing in class and extra-curricular activities, please rate them in order of importance to you.

We have included the three qualities of item (3) because of the importance attached to them by American Telephone and Telegraph through continuing studies since 1928. Unfortunately this separation caused confusion in some replies over whether any or all of these specific qualities were to be ranked among the five most desirable. Accordingly we have maintained the separation in reporting results.

In response to Item (1) we found that the electric utility group agreed it had found indicators of future success (24 "yes"—1 "no") to a greater degree than the industrial group (26 "yes"—10 "no"—3 "partially"—11 "no opinion"). There was surprising agreement in the qualities reported as "most desirable" by both groups. These reports also agreed pretty well with references (3) and (4) but differed widely with reference (5). It is probable that much of this disagreement arises from definition of terms. Reference (5) lists [illegible] different qualities or characteristics, many of which could be lumped under the various headings of this report as well as the headings of references (3) and (4).

The terms appearing in Table II are defined as follows:

(A) *Ability to do the job*—includes technical competence or ability indicated by good grades plus the drive to actually accomplish the work. Many saw extra-curricular accomplishment (not just spectator activity) as a good indicator of drive.

(B) *Ability to get along with others*—to cooperate fully and willingly

(C) *Personality*—lumps together, (in order of times reported), self sufficient, well rounded, pleasant

(D) *Ability to communicate*—writing and speaking proficiency

(E) *Interest in the industry*—genuine interest and enthusiasm for the job to be done

(F) *Work experience*—summer and co-op work record as an index of ability and self-reliance

(G) *Attitude*—interest in the work and a career before fringe benefits; enthusiasm

(H) *Initiative*—ability to think and act for himself within a guidance framework

(J) *Leadership*—demonstrated ability to lead harmoniously; management potential

That there is remarkable agreement between the qualities considered most desirable by our industrial and utility samplings is obvious. The only significant dis-

TABLE II — MOST DESIRABLE CHARACTERISTICS OF ENGINEERING RECRUITS

COMBUSTION SURVEY					
	INDUSTRIAL		UTILITY	REFERENCE 3	REFERENCE 4
34%	Ability to get the job done (A)	23%	Ability to get the job done (A)	Intelligence	Ability to get the job done (A)
19%	Ability to get along (B)	20%	Ability to get along (B)	Industry	Performance oriented
18%	Personality (C)	19%	Leadership (J)	Ability to get along (B)	Sense of Responsibility
12%	Ability to communicate (D)	14%	Personality (C)	Self Reliance	Ability to deal with people (B)
9%	Interest in Industry (E)	14%	Interest in Industry (E)		
8%	*Work experience (F)	10%	Attitude (G)		

*NOTE: (G) ATTITUDE AND (H) INITIATIVE TIED WITH (F) FOR LAST PLACE

placement between the two comes from the utilities higher ranking of *leadership* or management potential. Agreement with Reference (3) is good if we consider that intelligence and industry, ranked first and second, add up to *Ability to get the job done*, which placed first in our study. Self-reliance, ranked 4th in Reference (3), was the most frequently mentioned ingredient of *Personality* which placed third in industrial reports and fourth in the utility ranking. "Performance oriented," listed second in Reference (4) is amplified by Mr. Harrison, "It is not enough to accomplish things; the right things must be accomplished." This to us means judgement, technical and economic. This quality was mentioned a number of times but not frequently enough to make the first six. "Sense of responsibility" is explained in Reference (3) as "An engineer . . . must evidence the personal strength and determination to complete his assignments despite obstacles." This comes very c'ose to "drive" which is a vital part of our definition of *Ability to get the job done*.

The wide variation between the results shown in Table II and those of Reference (5) lead us to present these latter results separately. These rankings are based on qualities listed in a Western College Placement Bureau questionnaire and rated by 552 employers.

RANKING	QUALITY
1. . .	Integrity
2. . .	Ability to think logically
3. . .	Enthusiasm, initiative, drive
4. . .	Dependability
5. . .	Ability to communicate orally and in writing
6. . .	Emotional stability
7. . .	Ability to get along with others
8. . .	Evidence of good judgement
9. . .	Ability to make decisions
10. . .	Interest in career as opposed to "job" or salary
11. . .	Capacity for leadership
12. . .	Willingness to contribute to job development
13. . .	Maturity
14. . .	Adjustability
15. . .	General interest in type of work and kind of company
16. . .	Bearing, poise, self-confidence
17 . .	Good health
18. . .	Good manners
19. . .	Recognition of obligations to community, family and employer
20. . .	Physical appearance
21. . .	Scholastic standing
22. . .	Sense of humor
23. . .	Normal family life
24. . .	Reasonable freedom from limitations imposed by personal and family restrictions
25. . .	Extra Curricular activities
26. . .	Military status
27. . .	Marital status

It is extremely interesting to compare this list of desirable characteristics with the list compiled in COMBUSTION's survey (Table II). Note for instance that while integrity is ranked first in this list it did not re-

ceive a single mention in our study. We believe that had we offered a list of qualities and asked our respondents to rate them, integrity would have placed very high. That this quality received no mentions at all indicates only that employers expect integrity in all employees and hardly would hire an engineer known to lack it. On the other hand it would be difficult to name a trait more desirable than integrity from any given list containing the word.

Two other discrepancies struck us with considerable impact. Scholastic standing placed a poor twenty-first in a field of twenty-seven. Extra-curricular activities fared even worse, placing twenty-fifth in the field. These indicators were invariably mentioned high on the list by our respondents and of course, are two of the prime indicators used by the Bell System approach described below. We are quite at a loss to explain these radical variations and would welcome opinions from our readers on the subject.

School—Class Standing—Activities

In an earlier paragraph we mentioned that the questionnaire had requested a ranking of the three qualities discovered in 1928 as indicators of success in the Bell System and substantiated in later years—*quality of school, standing in class and extra-curricular activity.* The Bell study, based on 17,000 qualified case records, used annual salary compared to the salary of others with the same length of service as its criterion of success.

Table III, extracted from a Bell System report, shows the effect of *quality of school* and *standing in class* on salary levels achieved.

TABLE III—Rank, %, in College Graduating Class and College Quality as Related to Salary Progress

	Top Third of Class — Colleges			Middle Third of Class — Colleges			Bottom Third of Class — Colleges		
	Better	Average	Below Average	Better	Average	Below Average	Better	Average	Below Average
Top Salary Third	55	42	40	38	30	28	31	25	23
Middle Salary Third	30	35	38	38	36	38	33	33	37
Bottom Salary Third	15	23	22	24	34	34	36	42	40
	100%	100%	100%	100%	100%	100%	100%	100%	100 %

This study also concluded that "extra-curricular activity is, in fact, related to salary progress . . . extra-curricular achievement is somewhat compensatory for lower rank in class."

Before presenting the results of our survey concerning the desirability of these characteristics let us point out that about 20 per cent of the returns indicated that ranking should vary with the type of job being filled. For research positions, *quality of school* was considered vital with *standing in the class* a close second. A number observed that for a sales or administrative position they would look first to *extra-curricular activity* as an indicator of success.

There was a marked disagreement between the utilities and industrials here—utilities giving first place to *quality of school* in a 13 to 7 ratio while the industrials favored *standing in class* by 21 to 14 first place votes. This is odd when we consider that the utility group recruiting from prestige schools was below the national numerical index while industrial recruiting from the prestige group is well above the index (see Figs. 1 and 2). Table IV shows the voting for these qualities.

TABLE IV—Ranking of Scholarship Factors

Ranking		Industrials (Votes) 1st	2nd	3rd		Utilities (Votes) 1st	2nd	3rd
1st	Class Standing	21	13	1	Quality of School	13	4	5
2nd	Quality of School	14	9	12	Class Standing	7	11	4
3rd	Extra-curricular Activity	4	10	19	Extra-curricular Activity	4	16	12

Conclusions

1. If heavy research burdens are detracting from the quality of undergraduate education, employers are either not yet aware of it or are not overly concerned.

2. The single predominant factor in engineering recruitment is geography.

3. Extrapolation of the results of COMBUSTION's survey indicates that an amazingly large number of engineers are hired each year by companies having no formal, centralized program of recruitment or records of progress.

4. Agreement is excellent on the qualities most desired in candidates for engineering degrees; ability to get the job done, ability to get along with others, personality, interest in the industry or job, ability to communicate, leadership or management potential.

5. The qualities determined to be the best indicators of success in the Bell System by continuing study; (1. Quality of school, 2. Standing in class 3. Extra-curricular activities) were rated differently by our industrial and utility groups. The utilities rated *quality of school* first by a wide margin, probably because they tend to recruit from a small number of schools known to provide the type of training they need. The industrials, on the other hand, ranked *standing in class* first, probably because of the difficulty of rating the wider range of schools they draw from.

REFERENCES

(1) Keezer, D., "Financing Higher Education 1960–70," *McGraw-Hill Co.*, New York, 1959.

(2) Raudsepp, Eugene, "Inside the Engineer," *Machine Design*, 1960.

(3) Spencer, G. J., "Read Between the Lines of the Job Application," *Supervisory Management*, Oct. 1960.

(4) Harrison, H. L., "How to Develop First Line Supervisors," *Petroleum Refiner*, July, 1960.

(5) Western College Placement Bureau, "What Industry Looks for in the College Graduate," *Hughes Aircraft Co.*, 1960.

American Power Conference Program

THE twenty-third annual meeting of the American Power Conference will be held on March 21, 22, and 23 at the Sherman Hotel in Chicago.

The Conference is sponsored by Illinois Institute of Technology in cooperation with fourteen leading universities and nine national and regional societies throughout the United States.

Tuesday, March 21, 1961. 8:30 a.m. Registration
9:30 a.m.–12:00 Noon. Opening Meeting

Chairman: Thomas Ayers, Vice President, Commonwealth Edison Company, Chicago, Ill.
Co-Chairman: Burgess H. Jennings, Professor of Mechanical Engineering, Northwestern University, Evanston, Ill.

a. Invocation: The Reverend J. Donald Roll, S.J., Chairman, Physics Department and Director of the Seismological Station, Loyola University, Chicago, Ill.
b. William F. Crawford, President, Edward Valves Inc. and President, Republic Flow Meters Company, Subsidiaries of Rockwell Manufacturing Company, Chicago, Ill. "Our Changing Perspectives."

12:15 p.m. Joint APC-ASME Luncheon. Sponsored by the American Society of Mechanical Engineers

Chairman: William H. Byrne, President, American Society of Mechanical Engineers.
Co-Chairman: E. J. Carraro, Chairman, Chicago Section ASME.
Speaker: Sherman Knapp, President, Edison Electric Institute.

2:00–5:00 p.m. Central Stations I—Avon No. 8—A Supercritical Plant. Sponsored by the Power Division of ASME

Chairman: J. H. Harlow, Chief Mechanical Engineer, Philadelphia Electric Company, Philadelphia
Co-Chairman: H. L. Solberg, Associate Dean of Engineering, Purdue University, Lafayette, Ind.

a. "Initial Operation of Avon No. 8—A Supercritical Plant." N. F. Gill, Manager, Mechanical Engineering, Cleveland Electric Illuminating Company, Cleveland, Ohio.
b. "Supercritical Boiler Operating Experiences at Avon No. 8." J. I. Argersinger, Engineer, Research and Product Development, and Gordon C. Smith, Field Service Engineer, Combustion Engineering, Inc., Windsor, Conn.
c. "The Avon Superpressure Steam Turbine—Generator Unit." C. C. Franck, Sr., Consulting Engineer, and J. A. Carlson, Supervisory Engineer, Steam Division, Lester, Pa.

2:00–5:00 p.m. Water Technology I High Purity Water

Chairman: M. D. Baker, Chief Chemist, West Penn Power Company, Springdale, Pa.
Co-Chairman: G. A. Hellman, Associate Professor of Mechanical Engineering, Michigan College of Mining and Technology, Houghton, Mich.

a. "Effective Deaeration in Surface Condensers—Recent Experiences." Paul J. Hamm, Manager, Condenser and Pump Division, C. H. Wheeler Manufacturing Company, Philadelphia, Pa.
b. "A New Method for Increasing Sensitivity of Conductivity Measurement of Steam Purity." R. W. Lane, Chemist; C. H. Neff, Assistant Chemist, and T. F. Larson, Head, Chemistry Section, Illinois State Water Survey, Urbana, Ill.
c. "Application Considerations—Demineralization and Flash Evaporation." M. E. Gilwood, Director of development, Ionac Chemical Company, Birmingham, N. J., and J. Mack, Process Engineer, The Permutit Company, New York, both Divisions of Pfaudler Permutit Company, Inc., New York City.

2:00–5:00 p.m. Industrial I. Space Air Conditioning. Sponsored by American Society of Heating, Refrigerating and Air Conditioning Engineers

Chairman: Gilbert F. Carlson, Chief Engineer, Specialties Division, Bell & Gossett Company, Morton Grove, Ill.
Co-Chairman: William V. Richards, President, Illinois Chapter, ASHRAE, H. A. Phillips & Company, Chicago, Ill.

a. "Off Peak Electricity Using Stored Water for Space Heating." Stanley B. Tupper, Engineering Department, Bell & Gossett Company, Morton Grove, Ill. and Raymond J. Vertovec, Engineer, Electric Heat Technical Section, Commonwealth Edison Company, Chicago, Ill.
b. "A New Approach to Heat Pumps," Gilbert M. Warren, Sales Engineer, Carrier Air Conditioning Company, A Division of Carrier Corporation, Chicago, Ill.
c. "Thermoelectric Heating and Cooling Devices." J. D. Richards, Thermoelectric Products, Minnesota Mining and Manufacturing Company, St. Paul, Minn.
d. "High-Temperature High-Pressure Hot Water Heating." D. Lorne Lindsay, Professional Engineer, Wiggs, Walford, Frost and Lindsay, Consulting Engineers, Montreal.

8:00–10:00 p.m. Future Sources of Electrical Power

Chairman: L. Reiffel, Director of Physics Research, Armour Research Foundation, Chicago, Ill.
Co-Chairman: David C. White, Professor of Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass.

a. "Nuclear Fuel Celle Research," R. W. Henderson, Allison Division of General Motors, Indianapolis, Ind.
b. "The Status of Research in Thermonuclear Power." Sterling Colgate, Lawrence Radiation Laboratory, Livermore, Calif.
c. "Engineering Frontiers of Thermonuclear Power." C. W. Little, Jr., Director of Operations, C-Stellerator, Associates, Princeton, N. J.

Wednesday, March 22, 1961. 9:00 a.m.–12:00 Noon. Central Stations II. Commercial Operation of the Breed Plant

Chairman: Philip Sporn, President, American Electric Power Service Corporation, New York, N. Y.
Co-Chairman: Edwin H. Snyder, Vice President in Charge of Electric Operations, Public Service Electric and Gas Company, Newark, N. J.

a. "The Project." Philip Sporn, President, AEPSC
b. "The Plant." T. T. Frankenberg, Head, Mechanical Engineering Division, AEPSC
c. "Steam Generation." G. W. Bice, Assistant Head, Mechanical Engineering, Division, AEPSC
d. "Turbine." C. P. Lugrin, Head, Turbine Engineering Section, AEPSC.
e. "Chemistry." E. B. Morris, Head, Chemical Engineering Section, AEPSC.
f. "Generator and Electrical Features." C. P. Zimmerman, Head, Electrical Engineering Division, AEPSC.

Supported by the following papers and co-authors:

1. "Breed Plant." Philip Sporn, President and S. N. Fiala, Vice President and Chief Engineer, American Electric Power Service Corporation.
2. "Steam Generator." G. W. Bice, Assistant Head, Mechanical Engineering Division, AEPSC; Ed Griffin, Field Supervisor, Service

Engineering and Paul Koch, Manager of New Products, Examination Engineering, The Babcock & Wilcox Company.

3. "Turbine-Generator." P. G. Ipsen, Supervisor of Turbine Control Engineering; J. A. Massingill, Supervisor, Generator Electrical Engineering, General Electric Company; C. P. Lugrin, Head, Turbine Section and J. A. Oliver, Sr. Engineer, Electrical Engineering Division, American Electric Power Service Corp.
4. "Thermal Cycle Equipment and Performance." T. T. Frankenberg, Head, Mechanical Engineering Division and J. A. Tillinghast, Staff Engineer, American Electric Service Corporation.
5. "Instrumentation and Controls." A. S. Grimes, Head, Results Section and W. S. Morgan, Senior Engineer, AEPSC.
6. "Chemical Control and Chemical Cleanup." E. B. Morris, Head, Chemical Section, AEPSC.
7. Piping Systems. G. E. Lien, Head, Piping and Metallurgy Section and A. J. Breugelmans, Engineer, Mechanical Engineering Division, AEPSC.
8. Plant Electrical Features, Switching and Transmission. C. P. Zimmerman, Head, Electrical Engineering Division and T. J. Nagel, Head, System Planning and Analytical Division, AEPSC.
9. Civil Engineering Work, Coal Handling and Supply. H. A. Kammer, Executive Vice President, Engineering, Construction and Purchasing and E. A. Kammer, Head, Design Division, AEPSC.

9:00 a.m.–12:00 Noon. Automation and Control

Chairman: J. H. Kinghorn, Technical Vice President, Power Division, AIEE, American Electric Power Service Corporation, New York, N. Y.

Co-Chairman: M. Riaz, Professor of Electrical Engineering, University of Minnesota, Minneapolis, Minn.

a. "Automation of System Operation." L. K. Kirchmayer, Manager, System Generation Analytical Engineering and H. J. Fiedler, Application Engineer, System Protection and Control Engineering, Electric Utility Analytical Engineering Operation, General Electric Company, Schenectady, N. Y.

b. "Automatic Power Plants—Application of Control Computers." B. L. Lloyd, Manager, Generation Section, Electric Utility Engineering and R. E. Squires, Engineering Manager, System Control and Instrumentation Section, Power Control and Communications Department, Westinghouse Electric Corporation, East Pittsburgh, Pa.

c. "The Installation of Automatic Controls in an Existing Power Plant for Minimum Down Time." T. H. Bloodworth, Senior Systems Engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; J. A. Reich, Production Manager, Gulf States Utilities Company, Beaumont, Tex. and L. Merle Wilson, Manager, Milwaukee Operations for Consolidated Systems Corporation, Monrovia, Calif.

d. "Monitoring, Logging and Computing Performance for an Existing Coal and Oil Fired Station." Maurice J. Feldmann, Assistant Superintendent of Engineering and Construction and John W. Pursell, Jr., Assistant Superintendent of Production, Boston Edison Company, Boston, Mass.

9:00 a.m.–12:00 Noon. Fuels Sponsored by Fuels Division of ASME

Chairman: James R. Jones, Peabody Coal Company, Chicago, Ill.

Co-Chairman: Julian Meserve, Dow Chemical Company, Midland, Mich.

a. "Coal Properties as Related to the Corrosion of High Temperature Boiler Surfaces." J. T. Reese, Research Engineer and James Jonakin, Section Leader, Fuels Research, Combustion Engineering, Inc., Chattanooga, Tenn. and J. G. Koopman, Vice President, Electric Energy, Inc., Joppa, Ill.

b. "Liberation of Pyrite from Steam Coals." R. A. Glenn, Supervising Chemist and R. D. Harris, Project Engineer, Bituminous Coal Research, Inc., Columbus, Ohio.

c. "Effect of Pulverizer Design on Furnace Performance." H. M. Rayner, Mechanical Engineer, Western Electric Company and P. F. Seibold, Design Engineer, Riley Stoker Corporation, Worcester, Mass.

9:00 a.m.–12:00 Noon. Water Technology II Industrial III

Chairman: J. F. Wilkes, Director of Research and Development, Dearborn Chemical Company, Chicago, Ill.

Co-Chairman: A. B. Alter, Professor of Mechanical Engineering, Agricultural and Mechanical College of Texas, College Station, Tex.

a. "Some Practical Solutions to Industrial Water Treatment Problems." R. S. Walters Supervisor, Technological Coordination, Power Production Division, United States

Steel Corporation, South Works, Chicago, Ill.

b. "Boiler Scale Prevention by Use of Chelating Agents." J. C. Edwards, Power Engineer and E. A. Rozas, Chemical Engineer, Dow Chemical Company, Freeport, Tex.

c. "Effective Temperature Measurement of Boiler Wall Tubes to Provide Safe Operating Control." J. W. Strub, Consultant, Engineering Service Division, Engineering Department, E. I. DuPont de Nemours and Company, Wilmington, Del.

d. "Prevention of Corrosion in Steam Systems under Changing Load Conditions." Marcel Stein, Mechanical Engineer, Illinois Institute of Technology, Chicago, Ill.

12:15 p.m. APC–AIEE Luncheon Sponsored by the American Institute of Electrical Engineers

Chairman: Clarence H. Linder, President, American Institute of Electrical Engineers.

Co-Chairman: W. T. Larner, Chairman, Chicago Section AIEE, Illinois Bell Telephone Company, Chicago, Ill.

Speaker: George E. Drach, Illinois State Senator, Springfield, Ill.

Subject: "Federal Versus State Regulation in the Development of Atomic Power."

2:00–5:00 p.m. Nuclear Power Plants

Chairman: R. M. Casper, General Manager, Nuclear Power Division, Allis - Chalmers Manufacturing Company, Milwaukee, Wis.

Co-Chairman: C. W. Terrell, Supervisor, Reactor Physics Section, Physics Research Division, Armour Research Foundation, Chicago, Ill.

a. "The Technical and Economic Status of Central Station Gas Cooled Reactors." Titus G. LeClair, Manager, Nuclear Power Applications, General Atomic, San Diego, Calif.

b. "The Technical and Economic Status of Central Station Boiling Water Reactors." R. B. Richards, Manager of Engineering, Atomic Power Equipment Department, General Electric Company, San Jose, Calif.

"The Technical and Economic Status of Central Station Pressurized Water Reactors." John W. Simpson, Vice President, Atomic Power Department, Pittsburgh, Pa.

2:00–5:00 p.m. Symposium on Peaking—Thermal

Chairman: Rolland H. Bradford, Regional Manager, Central Region, Ebasco Services, Inc., Chicago, Ill.

Co-Chairman: R. C. Porter, Professor of Electrical Engineering, University of Michigan, Ann Arbor, Mich.

a. "Some Fundamental Factors Affecting Peaking." J. Howard Euston, Vice President Business Research Corporation, Chicago, Ill. and W. A. Lewis, Research Professor of Electrical Engineering, Illinois Institute of Technology, Chicago, Ill.

b. "Electromotive Power for Peaking Area Backup and Reserve." B. B. Brownell, Director of Research and Engineering, Electromotive Division of General Motors Corporation, La Grange, Ill.

c. "Gas Turbines for Peaking." W. D. Marsh, Application Engineer, Power Generation Engineering, Electric Utility Section, Schenectady, N. Y.

2:00–5:00 p.m. System Planning and Operation Sponsored by the Power Division of AIEE

Chairman: E. R. Moore, Manager of Engineering, the Detroit Edison Company, Detroit, Mich.

Co-Chairman: J. J. Carey, Professor of Electrical Engineering, The University of Michigan, Ann Arbor, Mich.

a. "Automation of System Planning." F. J. Maginniss, Manager, Special Studies and Digital Analysis Engineering, G. D. Galloway, Application Engineer, System Generation Analytical Engineering and A. J. Wood, System Generation Analytical Engineering, Electric Utility Analytical Engineering Operation, General Electric Company, Schenectady, N. Y.

b. "Results of a Year of Long Range Planning by Simulation." C. J. Baldwin, Generation Engineer, Electric Utility Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa. and J. A. Casazza, Transmission Planning Engineer, System Planning and Development Department, Public Service Electric and Gas Company, Newark, N. J.

c. "Coordinated Use of Hydro and Steam Generation in a Large Interconnected System." Ross N. Brudenell, Chief, System Loading Branch, Division of Power System Operations and Jack H. Gilbreath, Supervisor, Operation Planning Section, Division of Power System Operations, Tennessee Valley Authority, Chattanooga, Tenn.

d. "Daily Forecasting of Electric System Loads." S. S. Clair, Assistant Chief Load Dispatcher, Philadelphia Electric Company, Philadelphia, Pa.

2:00–5:00 p.m. Industrial IV—Central Station III—Steam Generators

Chairman: Chester R. Earle, Special Projects Editor, Power Engineering, Barrington, Ill.

Co-Chairman: D. J. Renwick, Associate Professor of Mechanical Engineering, Michigan State University, East Lansing, Mich.

a. "Preventing Furnace Explosions—The Application of Flame Detectors and Their Function in a Complete Furnace Protecting System." W. L. Livingston, Burner Group Leader and P. Gray, Jr., Research Engineer, Fuels Section, Kreisinger Development Laboratory, Combustion Engineering, Inc., Chattanooga, Tenn.

b. "Flue Gas Sampling and Analysis for O_2 in Cyclone Furnace Fired Boilers." F. C. Luxl, Field Engineer, Leeds and Northrup Company, Philadelphia, Pa., and J. J. Osochowsky, Results Engineer, Bridgeport Harbor Station, United Illuminating Company, Bridgepoint, Conn.

c. "Application of Centrifugal Compressors to Soot Blower Systems." J. W. Locke, Assistant Manager, Contract Engineering and R. G. Thesing, Contract Engineer, Diamond Power Specialty Company, Lancaster, Ohio.

2:00–5:00 p.m. Water Technology III—Condensate Polishing

Chairman: Louis F. Wirth, Jr., Manager, Ion Exchange Division, Nalco Chemical Company, Chicago, Ill.

Co-Chairman: T. J. Hodan, Sales Manager, Water Conditioning Section, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

a. "Plant Experience, High Flow Rate, Externally Regenerated Condensate Polishing Demineralizers, Dresden Nuclear Generating Station." A. P. Sisson, Chemical Engineer, Generating Stations, Commonwealth Edison Company, Chicago, Ill.; R. C. Reed, Systems Specialist, Atomic Power Equipment, Department, General Electric Company, San Jose, Calif. and H. W. Frazer, Manager, Ion Exchange Department, Infilco, Inc., Tucson, Ariz.

b. "Condensate Scavenging—Operating Results in Three Central Station Plants." V. J. Calise, General Sales Manager and J. A. Levendusky, Chief Research Engineer, Graver Water Conditioning Company, New York, N. Y.

6:30 p.m. All Engineers Dinner

Presiding: C. J. Forsberg, President, Wisconsin Power and Light Company, Madison, Wis.

Entertainment: Spartan Bell Ringers of Michigan State University.

Speaker: H. G. Ebdon, President, Combustion Engineering, Inc.

Thursday, March 23, 1961. *9:00 a.m.–12:00 Noon.* Central Stations IV *Sponsored by the Power Division of the American Society of Civil Engineers*

Chairman: M. P. Aillery, Chairman, Power Division, Executive Committee, ASCE, Chief Structural Engineer, J. G. White Engineering Company, New York, N. Y.

Co-Chairman: Richard N. Bergstrom, Associate, Sargent & Lundy, Engineers, Chicago, Ill.

a. "TVA's Paradise Steam Plant with 650,000-Kilowatt Units." R. A. Elliott, Chief Water Control Planning Engineer; W. F. Emmons, Chief Design Engineer and H. T. Lofft, Chief Construction Engineer, Tennessee Valley Authority, Knoxville, Tenn.

b. "Application of a Governor Test Facility to Analysis and Design of Steam Turbine Generator Control Systems." J. K. Dixon, Thermal Power Department, Allis-Chalmers Manufacturing Department, Milwaukee, Wis.

c. "Comparison of Contractual Arrangements for Utility and Industrial Projects." William E. Hopkins, Consulting Engineer, Stone and Webster Engineering Corporation.

d. "Cooling Pond or Cooling Tower?—An Overall Appraisal." W. R. Steur, Associate, Sargent & Lundy, Engineers, Chicago, Ill.

9:00 a.m.–12:00 Noon. Power Plant Auxiliaries Sponsored by the Power Division of ASME

Chairman: Charles D. Birget, Chief Mechanical Engineer, Commonwealth Associates, Inc., Jackson, Mich.

Co-Chairman: K. G. Picha, Associate Director, School of Mechanical Engineering, Georgie Institute of Technology, Atlanta, Ga.

a. "Philadelphia Electric Company Multi-Stage Flash Evaporator." C. Capara, Engineer, Mechanical Engineering Department and W. B. Willsey, Assistant Chief Chemist, Operating Department, Philadelphia Electric Company and D. Crane, Design Engineer, Heat Exchanger Section and E. F. Stalcup, Senior Negotiation Engineer, Sales, Heat Transfer Division, Westinghouse Steam Division, Lester, Pa.

b. "Corrosion and Vibration in Small Steam Turbines." Stanford Neal, Manager Advance and Development Engineering, and W. J. Caruso, Structural Engineer, Small Steam Turbine Department, Gen-

eral Electric Company, Fitchburg, Mass.

c. "Second Progress Report on High Speed Boiler Feed Pumps." Igor J. Karassik, Consulting Engineer and Manager of Planning and Elliott F. Wright, Chief Engineer, High Pressure Pumps, Harrison Division, Worthington Corporation, Harrison, N. J.

d. "Development and Operation of Fluid Drives for Turbine-Generator Driven Boiler Feed Pumps." R. D. O'Neil, Product Manager, Fluid Drives, American Standard, Industrial Division, Detroit, Mich.

12:15 p.m. Joint APC—WSE Luncheon Sponsored by the Western Society of Engineers

Chairman: Raymond D. Maxson, President, Western Society of Engineers.

Co-Chairman: Joseph C. Boyce, Vice President and Dean of The Graduate School, Illinois Institute of Technology.

Speaker: Titus G. LaClair, Manager, Nuclear Power Applications, General Atomic, San Diego, Calif.

Subject: "The Future of Atomic Energy."

2:00–5:00 p.m. Central Stations V

Chairman: Ben G. Elliott, Professor Emeritus of Mechanical Engineering, University of Wisconsin, Madison, Wis.

Co-Chairman: Reno C. King, Associate Professor of Mechanical Engineering, New York University, New York, N. Y.

a. "Improvement in Economics of a 625 Mw Combined Cycle Plant Over a Conventional Steam Cycle Plant." H. J. Peterson, Vice President and Power Consultant, United Engineers and Constructors, Inc., Philadelphia, Pa. and J. O. Stephens, Manager of Engineering-Gas Turbines, Westinghouse Electric Corporation, Lester, Pa.

b. "Binary Cycle for Power Generation —Steam—Peyton—12 System." David Aronson, Consultant, Advanced Products Division, Worthington Corporation, Harrison, N. J.

2:00–5:00 p.m. Industrial VI—Economics of Power Plant Operation

Chairman: Kenneth R. Hodges, Chief Engineer, Sears Roebuck and Company.

Co-Chairman: Roy Sahlstrom, Faville LeVally Corporation, Chicago, Ill.

a. "How Small Plants Can Conserve Utilities and Reduce Cost." George R. Chadwick, Consulting Engineer, Chicago, Ill.

Advertisers' Index

(Continued on page 63)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